PNWD-3521

Investigations of migratory bull trout (*Salvelinus confluentus*) in relation to fish passage at Albeni Falls Dam

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FINAL REPORT

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Executive Summary

Bull trout, *Salvelinus confluentus*, of the Columbia Basin were listed as a threatened species by the United States Fish and Wildlife Service (USFWS) in 1998 under the authority of the Endangered Species Act (ESA). The USFWS 2000 Biological Opinion determined that after Albeni Falls Dam was constructed on the Pend Oreille River in 1952, bull trout abundance below the dam decreased to the point that individual fish were noteworthy. In consultation with U.S. Army Corps of Engineers (USACE), the USFWS directed the USACE to investigate the feasibility of restoring fish passage at Albeni Falls Dam.

Prior to the construction of Albeni Falls Dam, salmonids were known to freely pass Albeni Falls in both up and downstream directions. Fish passage would provide upstream access to bull trout that may have elected to migrate downstream over the dam or were passed through the dam and were trying to return to their natal tributary to spawn. Fish passage also has the potential to provide riverine bull trout access to the cold waters of Lake Pend Oreille when water temperatures in the lower Pend Oreille River exceed lethal levels for bull trout. As summer temperature conditions in the mainstem of the Box Canyon Reach (between Box Canyon and Albeni Falls dams) is presently inhospitable to bull trout and it appears little can be done to correct this problem, it places a premium on bull trout being able to migrate to a cold water refuge such as Lake Pend Oreille.

In an effort to better understand bull trout interactions with Albeni Falls Dam, a suite of investigations were initiated in 2002. In one study, we collaborated with the Idaho Department of Fish and Game to radio track the movements of six post-spawning bull trout from the Middle Fork East River, a tributary of the Priest River. The Priest River is the closest river with a population of bull trout upstream (8 km) of the dam, so we reasoned that movements of bull trout to and from their spawning grounds in this river could result in them entering the forebay of the dam and becoming entrained. Following spawning (September), these fish migrated rapidly down the Priest River, then up the Pend Oreille River to overwinter in Lake Pend Oreille or in the river below the lake's outlet. None of these fish approached Albeni Falls Dam. During May-July 2003, all of the fish with functional transmitters migrated rapidly downstream, and then up the Priest River to the Middle Fork East River, i.e., they homed to the same spawning tributary used the previous year. None of these fish approached Albeni Falls Dam on their return migration.

In a second study, conducted in the spring/summer 2003, a total of 131 juvenile bull trout, 76-169 mm FL, were captured by snorkeling in the Middle Fork East River. These fish were marked with passive integrated transponder (PIT) tags. Assuming that some of these fish out-migrated in the fall of 2003 or spring 2004, it was anticipated that they might be collected during electrofishing surveys below the dam in 2004 and thus provide information about the magnitude of entrainment of juvenile out-migrants.

In a third study, electrofishing surveys conducted in the tailrace in July and August 2003 found 10 bull trout, nine in a culvert one km below the dam that provided a cold water refuge (15 ºC), and one at Indian Creek 14 km below the dam that also provided a cold water refuge (18 ºC). Ambient water temperatures in the river exceeded 25 ºC, which was above the thermal tolerance of bull trout. These fish, 435-722 mm FL, were likely washouts from above the dam. If these fish originated in spawning tributaries below Albeni Falls Dam, they probably would have sought thermal refuge in their home streams. Instead, the fish were congregated close to the dam in the coldest water available. Radio tracking of seven individuals released at the culvert indicated that they were using it as a staging area in what appeared to be futile attempts to find upstream passage. In 2004, we attempted to further address this question by moving bull trout above the dam and tracking their movements.

In 2004, investigations of bull trout behavior in relation to Albeni Falls Dam continued. Our objectives were to:

1) Repeat electrofishing surveys to determine if additional bull trout could be detected below Albeni Falls Dam. Sampling was expanded to monthly surveys

between May and November. This time period was chosen to encompass times that were more biologically appropriate to encounter migrating bull trout.

2) Evaluate the potential of using the culvert for a trap-and-haul facility as a low cost alternative to passage facilities at the dam. The culvert was associated with a small spring that flows at a constant temperature of 9 ºC. In 2003, bull trout were concentrated in the cold water there when ambient temperature of the river exceeded the thermal tolerance of bull trout in July. However this was not an appropriate time to transport fish around the dam because the river temperature was too warm for migration. Hence, we needed to determine if bull trout could be collected at the culvert in the spring and fall when the culvert temperatures were closer to the river temperature and bull trout were more likely to be in a migratory state.

3) Conduct radio-telemetry investigations with bull trout captured in the tailrace and transported above the dam to determine if they migrate upstream (to Lake Pend Oreille or tributaries of the lake or river above the dam) or downstream (below the dam). If the fish moved upstream after release, especially if they moved into tributaries of the lake or river at biologically appropriate times for spawning, it could be inferred that the fish had passed over Albeni Falls Dam, which prevented migration back to home spawning tributaries.

In 2004, a total of 2,113 fish (22 species) were captured in the Pend Oreille River between Indian Creek and Albeni Falls Dam during 12.33 hours of boat electrofishing. Two bull trout were collected during these surveys, representing 0.1% of the relative abundance and catch-per-unit-effort (CPUE) was 0.2 bull trout per hour. One fish was found at the mouth of the culvert, where the majority of the bull trout were found the previous year. The other fish was collected near the boat launch 2.8 km below Albeni Falls Dam. Neither fish had been previously marked. Bull trout tagged with PIT tags during the 2003 study in the Middle Fork East River, that may have out migrated during the fall of 2003 or winter/spring 2004, were not found below the dam.

In addition to the bull trout, lake trout (n = 2), lake whitefish (n = 2), and kokanee (n = 3) were also recorded. These three non-indigenous species are common in Lake Pend Oreille, but not in the Pend Oreille River below Albeni Falls Dam.

In May 2004, the Washington Department of Fish and Wildlife (WDFW) and the Kalispel Tribe captured 15,525 fish at 126 randomly selected electrofishing sites, 64 fyke net sites, and 56 gill net sites between Box Canyon and Albeni Falls dams. Our surveys in May were coordinated with this effort. We were assigned the reservoir section between Indian Creek and Albeni Falls Dam. No gill nets were set in this area to avoid killing bull trout.

No bull trout, lake trout, lake whitefish, or kokanee were collected anywhere in the reservoir during 2004, except in the segment between Indian Creek and Albeni Falls Dam. In fact, all of the individuals of each species were collected upstream of the U.S. Highway 2 bridge (i.e., in the tailrace area). Therefore, we inferred that their presence below the dam was probably related to either entrainment (non-volitional drawing of fish in the forebay through the water intake structures or over the spillway of the dam) or volitional movements (associated with a programmed fluvial or adfluvial migratory life history between tributaries of Lake Pend Oreille or Pend Oreille River above the dam to feeding areas in the Pend Oreille River below the dam).

It was determined that the elevation of the river determines if river water is flowing into the culvert or if spring water is flowing out of the culvert. Comparing reservoir elevation in 2003 and 2004 we were able to determine that if the Pend Oreille River was above 2,035 ft (620.3 m), the river flows into the culvert and forces cold spring water to flow out the far side into a wetland located on the opposite side of the railroad causeway. When the river elevation dropped below 2,035 ft, cold (9 °C) spring water flowed out of the culvert into the river and made the entire length of the culvert (and a scour pool on the river side of the culvert) a cold water refuge.

We concluded the culvert would not make an acceptable trap and haul site because during the entire spring migration the elevation of the river was above the rim of the culvert and river water flowed into it. As no cold water flowed out, there was nothing to attract fish. The flow into the culvert did not switch direction until the water of the river warmed above 18 °C, when it would not be advisable to transport fish.

The two bull trout collected in June 2004 below Albeni Falls Dam were successfully implanted with radio transmitters and PIT tags. Both fish were transported 7.5 km above the dam and then released in the Pend Oreille River 0.5 km downstream of the Priest River. Both fish moved quickly to Lake Pend Oreille. The first fish traveled 27.2 km in 21.5 hrs to the Dover Bridge. The fish entered Lake Pend Oreille where it went undetected until aerial flights on 30 August detected it in Lightning Creek (a tributary to the Clark Fork River), where it presumably spawned. The total distance traveled by the fish in one direction from its release point to Lightning Creek was 72.4 km. Subsequent flights did not detect the fish again, and we assume it returned to Lake Pend Oreille. Stationary receiver stations were monitored through 5 November, and the fish did not move out of the lake past Dover Bridge by that time.

The second fish moved past the Dover Bridge 14.5 hrs after it was released from the boat launch at Priest River. This fish also presumably entered Lake Pend Oreille. It was not detected during any of the subsequent tracking surveys. This fish either stayed in Lake Pend Oreille or entered a tributary that we did not survey.

In one sense, the behavior of two bull trout captured below and transported above Albeni Falls Dam in June 2004 provided the strongest support for the hypothesis that these adult fish had originated from tributaries above the dam. Instead of dropping back down below the dam, both radio-tagged bull trout migrated rapidly into Lake Pend Oreille and one of them was detected in Lightning Creek, a spawning tributary on the Clark Fork arm of Lake Pend Oreille.

Fewer bull trout were captured in 2004 ($n = 2$) than in 2003 ($n = 10$), even though more electrofishing effort was expended in 2004 (12.33 hours) than in 2003 (5.3 hours). CPUE was 0.2 bull trout per hour in 2004 (based on 2 fish collected in relative abundance surveys) compared to 1.2 bull trout per hour in 2003 (based on 6 fish caught during relative abundance surveys). Whether the 6-fold difference in CPUE between years is statistically significant is unknown because only two years of catch rates are available. However, the 10-fold increase in CPUE in the tailrace over the CPUE reservoir wide is notable and suggests that entrainment or volitional movements, rather than random chance, is a valid explanation for the bull trout present in the tailrace of Albeni Falls Dam.

The hypothesis that the number of bull trout collected below the dam was positively related to increased discharge was weakly supported because only two years of data were available to conduct the analysis. Discharge and bull trout capture were both higher in 2003 than 2004. The mean (maximum) annual discharge of the Pend Oreille River at the gauge below Albeni Falls Dam in 2003 was 24.2 thousand cubic feet per second (KCFS) (67.8 KCFS) while in 2004 the mean (maximum) discharge was 20.5 KCFS (51.9 KCFS). These values were all below the long-term average (maximum) discharge of 24.6 KCFS (138.2 KCFS) measured at Albeni Falls Dam during the period of record (1960-2004). Thus, although there was a difference in discharge between 2003 and 2004, it was a subtle difference in relation to discharge measured over the period of record and we are uncertain if this would be a sufficient difference to account for the large difference in number of bull trout observed each year. Additional sampling would need to be accomplished in order to determine if the number of fish found below the dam increases with increasing discharge.

Because river discharge was relatively low (below average for the period of record) in both years of our study, the fish we recovered might represent a minimum estimate of bull trout being washed over the dam. We suspect that the numbers could be higher in years with above average discharge.

To assess whether transportation of bull trout above Albeni Falls Dam might be expected to benefit locally adapted bull trout populations in Lake Pend Oreille tributaries, a comparison was made between the number of bull trout spawners in tributaries of Lightning Creek to the recommended number needed to protect genetic variation in a locally adapted bull trout population. Lightning Creek was selected because one of our study fish entered this tributary to Lake Pend Oreille.

In a study specific to bull trout, Rieman and Allendorf (2001) determined that 100 bull trout spawners were needed to prevent inbreeding depression (which causes immediate change in heterozygosity and allele frequencies in a population and shifts it out of equilibrium). A population of 1000 individuals would be needed to maintain local (adaptive) genetic variation for centuries (i.e., there is little loss of heterozygosity and allele frequency remains in the theoretically stable Hardy-Weinberg equilibrium). At population levels of about 500 individuals, they estimated that bull trout lost about 10% of their heterozygosity every 200 years.

Microsatellite DNA studies had previously shown that each tributary of Lightning Creek contains its own reproductively isolated spawning population of bull trout, which is apparently maintained by precise reproductive homing (Spruell et al. 1999). Neither the main stem Lightning Creek nor any tributary met the criteria of 1000 fish needed to protect genetic variability indefinitely in either 2003 or 2004. Only one tributary to Lightning Creek in 2004 and none in 2003 met the criteria of 100 fish needed to minimize the risk of inbreeding. The estimated minimum spawning escapement was less than 20 fish in six streams in 2003 and less than 30 fish in five of the streams in 2004. Using the population guidance rules of Rieman and Allendorf, the probability of extinction of each of these populations is high. Consequently, one individual bull trout transported above Albeni Falls Dam and migrating into any of these tributaries could potentially have contributed important genetic information to those populations.

Genetic samples collected during our study (n = 10 in 2003 and n = 2 in 2004) were turned over to the Kalispel Tribe for a genetic inventory of bull trout in the Pend Oreille Basin (Maroney et al. 2003; Olson et al. 2004). Examination of the protocols for the genetic survey revealed no plans to collect bull trout from tributaries in Lake Pend Oreille because microsatellite DNA studies on those populations had previously been published (Neraas and Spruell 2001; Spruell et al. 1999). However, the loci being examined by Maroney et al. (2003) and Olson et al. (2004) were not the same as those examined in previous studies. Therefore, as it is presently conceived, the current survey will not be comparable to other studies.

It would also be useful to collect a larger sample size of bull trout below Albeni Falls Dam for the genetic analysis. The present number of bull trout genetic samples from the tailrace area is relatively low (n = 12). The bull trout found in Box Canyon Reservoir are assumed to originate from above the dam. The current genetic analysis should be able to determine which population each fish is genetically similar to. Increasing the sample size of fish from the tailrace area of Albeni Falls Dam would better enable geneticists to determine if these fish are from populations above or below the dam. An sample size of 50 individuals is an accepted standard for genetic investigations with depleted populations and should be a target number for bull trout below Albeni Falls Dam. Although we recognize this target may not be achieved, increasing the sample size by even 10 individuals would greatly improve the genetic analysis.

Based upon the results of this study we make the following conclusions/ recommendations regarding the biological benefits of fish passage at Albeni Falls Dam:

1. Facilitate migratory fish passage at Albeni Falls Dam. Results obtained during this study were consistent with the hypothesis that Albeni Falls Dam is a barrier to the movement of bull trout in the Pend Oreille River – Lake Pend Oreille watershed. Bull trout originating from tributaries of Lake Pend Oreille and other tributaries upstream of Albeni Falls Dam were captured below the dam. The radio telemetry data suggests that these adult fish were attempting to move back upstream to home spawning tributaries. The number of adult spawners entering most tributaries of Lake Pend Oreille is currently very small and their populations will benefit if small numbers (n = 2 to 10) of individuals are transported above the dam and added back to the tributary population from where they came. Such populations will benefit from adding genes back to the population that would otherwise have been lost. Their population abundance may expand because of increased reproductive potential associated with large, fecund migratory individuals. Bull trout captured below the dam should be released above the dam

and allowed to migrate on their own volition to the tributary of their choice. This "lets the fish decide" where it wants to go and even gives them the option of returning below the dam in the event their home tributary is not located above it.

2. A pilot-scale fish passage evaluation should be employed to determine the most effective means to pass fish over Albeni Falls Dam. If low numbers of adult bull trout return to the base of the dam, it may be more cost effective to construct a trap-and-haul facility and transport fish above the dam individually. If large numbers of adults return to the base of the dam, it may be more cost effective to construct a fish ladder so individual fish would not have to be handled. We suggest that two types of trap-and-haul options might be employed. One possibility is a trap constructed at the base of the log chute. Advantages of a trap at this location include its apparent attractiveness to salmonids and security. Disadvantages include that it is close to the turbulent waters of the spillway and powerhouse, which will likely provide competitive attraction flows. A second possibility is construction of a floating trap on a pontoon barge. One advantage of this type of trap is that it could be moved around to different positions in front of the dam to determine locations that provide the best attraction flows. Disadvantages are that it would not be as secure as a land-based facility on USACE property and potential problems with anchoring in strong currents. Attractiveness of both traps might be improved by adding small quantities of water from Lake Pend Oreille or Priest River tributaries to them.

3. Commencing in 2005, attempts should be made annually (in June) to collect bull trout below the dam by electrofishing. This would serve three purposes. First, it would result in the collection of more fish to improve genetic comparisons. Second, it would enable testing of the null hypothesis that there is no relationship between discharge and number of bull trout found below the dam. (The alternate hypothesis that the number of bull trout found below the dam is positively related to increased discharge would be supported if the null hypothesis was rejected and more bull trout were captured in years with high discharge than in years with low discharge.) Third, it would allow bull trout captured below the dam to be

transported above the dam. Concurrent telemetry studies and PIT tagging of transported fish would allow for a direct assessment of whether these fish contributed in a genetically meaningful way to their spawning population (by comparing the number of transported fish returning to a particular tributary with the estimated spawning escapement into that tributary). In the present study only radio transmitters were used and radio signals were apparently attenuated by depth making it impossible to track the fish after they entered Lake Pend Oreille. Future biotelemetry studies should incorporate implanting adult bull trout with dual ultrasonic and radio transmitters so their movements can be followed after they enter the deep waters of Lake Pend Oreille. This would increase the probability that adult bull trout could be successfully tracked to their spawning tributary. Electrofishing is a less desirable method for collecting bull trout (because it is more stressful to the fish) than allowing them to migrate into a trap, so as soon as a trap facility becomes available it should replace electrofishing as the collection method for performing these studies. Angling could be used in place of electrofishing to capture bull trout, although angling of large bull trout could potentially be as stressful as electrofishing.

4. Conduct additional studies to characterize the juvenile out-migration of bull trout from the Middle Fork East River. One of the objectives of our original study was to monitor the first out-migration of juvenile fish into the Pend Oreille River. We suspected that first-time migrants might be prone to swim downstream and, after entering the Albeni Falls forebay, be subjected to entrainment. In trapping and snorkeling surveys conducted during the spring and summer 2003 (21 April to 10 July), we determined that the largest juveniles present were probably not large enough to be migrants and none of the 15 largest fish tagged with short-lived (two week) radio-transmitters emigrated out of the Middle Fork during this period (Geist et al. 2004), so that our objective of assessing the behavior of these fish following their entry into the Pend Oreille River remained unaccomplished. We concluded that it was probable that juvenile out-migrant bull trout in the Middle Fork East River have adapted to a fall emigration schedule and proposed to

conduct studies during the fall of 2004 to address our original objective. However, insufficient funding in 2004 precluded this work. We still believe that it would be important to accomplish this objective because the Middle Fork East River population resides closer to Albeni Falls Dam than any other, so it seems likely that entrainment would be more likely to occur with individuals from this population than any other. Telemetry (radio or acoustic), using miniature long-lived transmitters, would be the most suitable method to accomplish this objective.

5. The current genetic inventory being compiled for bull trout in the Pend Oreille Basin downstream from Lake Pend Oreille with funding from the Bonneville Power Administration should be reassessed to assure that accurate genetic comparisons can be made with bull trout populations in tributaries of Lake Pend Oreille and the Clark Fork River. In particular we recommend that the current study be either be expanded to include genetic samples of bull trout from Lake Pend Oreille tributaries or the WDFW Genetics Lab performing the work screen the following microsatellite DNA loci which were used for previously published microsatellite DNA investigations of bull trout in Lake Pend Oreille and Clark Fork River: *OCL* 12, *OGO* 2, *ONE* µ7, *OTS* 101, *SCO* 19, *SFO* 18, *SSA* 311, and *SSA* 456.

Introduction

Bull trout, *Salvelinus confluentus* (Suckley, 1858), of the Columbia Basin were listed as a threatened species by the United States Fish and Wildlife Service (USFWS) in 1998 under the authority of the Endangered Species Act (PL 93-203) of 1973 as amended (U.S. Fish and Wildlife Service 1998). In their 2000 Biological Opinion, the USFWS noted that, after the construction of Albeni Falls Dam in 1952, bull trout abundance in the Pend Oreille River (Idaho and Washington) downstream of the dam decreased to the point that individual fish were noteworthy and directed the United States Army Corps of Engineers (USACE) to investigate the feasibility of restoring fish passage at the dam (U.S. Fish and Wildlife Service 2000). In 2002, the USACE entered into a contract with Battelle Laboratories, Pacific Northwest Division, to perform this study. The purpose of this project was to describe the movements of migratory bull trout in relation to Albeni Falls Dam on the Pend Oreille River. This work continued radio-telemetry investigations initiated in 2002 to clarify questions regarding passage of bull trout at Albeni Falls Dam (Geist et al. 2004).

This report: 1) briefly reviews work on this project conducted in 2002 and 2003, and 2) presents the results of work conducted in 2004. Appendix 1 is a review of the literature on the migratory habits of bull trout, and description of bull trout in the Pend Oreille/Clark Fork Basin which was compiled to help us better understand and interpret the results of these studies.

Previous Work (2002-2003)

In 2002 and 2003, juvenile and adult bull trout captured in the Middle Fork East River, a tributary of the Priest River which enters the Pend Oreille River 8 kilometers (km) above Albeni Falls Dam, were implanted with radio transmitters and tracked to determine if their fluvial or adfluvial migrations brought them into the vicinity of Albeni Falls Dam forebay where there was potential for them to become entrained. Additionally, we implanted radio transmitters in adult bull trout captured in the tailrace below Albeni Falls to determine their interaction with the dam. Movements of tagged fish were determined by: 1) downloading data from fixed radio-receiving stations located at Albeni Falls Dam, the mouth of the Priest River, and the railroad bridge at Dover, Idaho; and 2) conducting mobile tracking surveys from boat, airplane or automobile.

Our investigations in 2003 confirmed and extended the results of radio-tracking studies in 2002 by the Idaho Department of Fish and Game (IDFG) that bull trout spawning in the Middle Fork East River made adfluvial migrations to overwintering sites in Lake Pend Oreille (Dupont and Horner 2004). IDFG tagged 20 pre-spawning adult bull trout in the Middle Fork East River in July and August 2002. After spawning in September 2002, 14 of these fish suffered post-spawning death and the six remaining fish, 450-732 mm FL, migrated down the East and Priest rivers, then up the Pend Oreille River. Two of these fish apparently remained in the Pend Oreille River and four reached the lake. The latter fish were detected by stationary receivers placed on the Dover railroad bridge and/or by mobile tracking near the U.S. Highway 95 bridge in November or December 2002, passing in an upstream direction. These fish were presumed to have overwintered in deep waters of Lake Pend Oreille, which attenuated their radio signals, making them undetectable during mobile tracking from vehicles and airplanes in the winter of 2002/2003.

Our observations in 2003 further indicated that one of the fish which remained in the Pend Oreille River returned to the East River in July 2003. Additionally, two of the fish that migrated to the lake returned to the East River in May-July 2003. The first fish was recorded passing a stationary receiver at the mouth of the Priest River on December 9, 2002 and at various locations in the Pend Oreille River during aerial surveys in the winter of 2002/2003. It was undetected from 23 February until 1 July, 2003, when it was relocated in the East River. As the radio signal from this fish was not recorded at either the Dover or U.S. Hwy 95 bridge we assume it remained in the Pend Oreille River.

The second fish was in the East River on 9 December, 2002 and passed the Dover railroad bridge in an upstream direction on 11 December, 2002. It was undetected from then until 24 May, 2003 at which time it was detected passing the Dover bridge in a downstream direction. The fish was subsequently detected at the mouth of the Priest

River on the same date, in the lower Priest River on 17 June and in the Middle Fork East River from 18 June to 2 September, 2003.

The third fish was detected at the U.S. Hwy 95 bridge from 14 November 2002 to 4 February 2003, then was undetected until 15 May 2003, when it was detected at the Dover bridge. It remained near the Dover bridge until 25 May, on which date it was also detected at the mouth of the Priest River. It was subsequently detected in the Middle Fork East River from 17 June to 2 September, 2003.

Contact with the other three fish was lost before we could determine if they returned to the Priest River drainage, although one of these fish had begun a downstream migration out of Lake Pend Oreille and was last detected between 18 June and 7 July, 2003 at the Dover railroad bridge. Either the transmitter failed at that time (as it was nearing the expected end of its battery life) or the fish returned to the lake where it was undetected.

Collectively, movements of these adult bull trout provided evidence of roundtrip fluvial and adfluvial migrations between a tributary of the Priest River and the Pend Oreille River or Lake Pend Oreille. Adult fish migrated out of their spawning tributary (Middle Fork East River) after the spawning season and down the Priest River. After entering the Pend Oreille River, some of these fish migrated rapidly upstream to overwinter in Lake Pend Oreille (adfluvial life history) or remained in the Pend Oreille River upstream of the confluence of the Priest River (fluvial life history). None of these adult fish migrated downstream upon entering the Pend Oreille River. All of the fish that were still being tracked returned to the same spawning location used the previous year in May and June of the following year. Repeat homing by iteroparous adult fish was consistent with the hypothesis that bull trout exhibit fidelity to natal spawning sites, similar to other salmonids (Hasler and Scholz 1983). However, it was not confirmed if the Middle Fork East River was the birth stream of these fish.

The fish returned to their spawning tributary between 24 May and 1 July, before temperature of the Pend Oreille River became too warm for migration. Thus their migration timing appeared to be an adaptive response to local environmental conditions.

The fish traveled rapidly down the Pend Oreille River into the Priest River, and did not overshoot it. (Two fish traveled from the Dover railroad bridge to the mouth of the Priest River, a distance of 26.6 km, in less than 24 hours and immediately entered the Priest River.) None were detected by radio receiver stations that continuously monitored the forebay of Albeni Falls Dam. The fact that neither pre-spawning adult nor post-spawning adult migrants were detected in the forebay suggested that entrainment associated with overshooting by adult fish of the East River population may be minimal.

The second objective in 2003 was to investigate the behavior of sub-adult bull trout from the Middle Fork East River migrating into the Pend Oreille River for the first time. Our aim was to determine if, after entering the Pend Oreille River, they behaved like adults and migrated rapidly upstream to Lake Pend Oreille or if they had a greater tendency to migrate downstream into the forebay of Albeni Falls Dam, where they could be subjected to entrainment. We captured juvenile migrants in a rotary screw trap set at the mouth of the Middle Fork East River and by electrofishing and snorkeling with hand nets in the Middle Fork East River. The trap was operated from 21 April to 22 August 2002 but failed to catch any downstream migrating bull trout. Electrofishing/snorkeling surveys, conducted from mid-June to early July resulted in the capture of 131 juvenile bull trout.

Fifteen of the largest fish (FL = 136-169 mm) were implanted with miniature radio transmitters and passive integrated transponder (PIT) tags. The remainder received PIT tags. All of the transmitter implanted fish remained in the vicinity of their capture site; none moved out of the Middle Fork East River into the Priest or Pend Oreille River during the life of the transmitter (approximately 2-3 weeks). Thus, we were unable to evaluate the behavior of first-time juvenile bull trout migrants upon entering the Pend Oreille River or their behavior in relation to Albeni Falls Dam. Juvenile bull trout in the Pend Oreille Basin emigrated from their natal streams typically at age 3 or 4, at lengths of 170-300 mm (Pratt 1985; Pratt and Huston 1993). No fish of this size was found in the Middle Fork East River during our sampling in 2002, suggesting that juvenile adfluvial fish in the East Fork Priest River emigrate downstream in the autumn or early spring (before mid-April). If so, their behavior would be different than other populations of bull trout. In the Flathead Basin, Montana, juveniles out-migrated from tributaries of the upper Flathead System into Flathead Lake throughout the late spring and summer (Shepard et al. 1984; Fraley and Shepard 1989). In the Metolius River, Oregon, bull trout (predominately age 2 juveniles) out-migrated from tributaries into a main stem reservoir during May and June, primarily at night (Ratliff et al. 1996).

The third objective in 2003 was to determine if adult or juvenile bull trout collected by electrofishing from the tailrace of Albeni Falls Dam bore marks indicating that their origin was from a tributary of the Pend Oreille River or lake above the dam. We were looking for marked fish because, since 1995, substantial numbers of juvenile and adult bull trout in tributaries of Lake Pend Oreille were marked by fin clipping or PIT tagging, so the electrofishing operations were conducted in 2003 to determine if any of these fish could be detected below Albeni Falls Dam. In 1999, an adult bull trout that had originally been marked with an adipose fin clip as a juvenile in either Lightning or Trestle creeks (tributaries located respectively on the Clark Fork arm and north shore of Lake Pend Oreille) was recaptured in a migration trap set in Indian Creek, a tributary on the right bank of the Pend Oreille River located 14 km below Albeni Falls Dam (Lockwood et al. 2001). The fish was marked with a floy tag and was subsequently caught by an angler in June 2000 near the mouth of Marshall Creek, which is located between Indian Creek and Albeni Falls. The recovery of this fish below Albeni Falls Dam demonstrated that some fish from the Pend Oreille Basin in Idaho either become entrained at or move volitionally below Albeni Falls Dam.

Additionally, from 1987 to 2002 several fisheries projects had been conducted in Box Canyon Reservoir between Box Canyon and Albeni Falls Dams (RKM 55.5-145.0). These included reservoir-wide electrofishing, gill netting and beach seine surveys from 1987-1992 and 1997 by Eastern Washington University (Barber et al. 1989a, 1989b, 1989c, 1990; Ashe 1991; Ashe et al. 1991a, 1991b; Clark 1991; Ashe and Scholz 1992; Skillingstad 1993; Skillingstad et al. 1993; Scholz 1998), reservoir-wide electrofishing, gill net, beach seine and pop net surveys made by the University of Idaho from 1986-1991 (Bennett et al. 1990; Bennett and Liter 1991; Bennett and Garrett 1994), and electrofishing surveys focused in the vicinity of the Kalispel Indian Reservation, RKM 105.7-117.9, by the Kalispel Tribe Department of Natural Resources from 1995-2003

(KNRD and WDFW 1996, 1997, 1998; Anderson 2000, 2002; Lockwood et al. 2001; Anderson and Olson 2003, Conner et al. 2003a, 2003b; Olson and Anderson 2004). Collectively, these surveys captured a total of 95,550 fish but only seven bull trout throughout the Box Canyon Reservoir.

In 2003, our intention was to focus electrofishing effort in the section of Box Canyon Reservoir immediately below Albeni Falls Dam to determine if bull trout were more abundant in that reach than they were reservoir-wide. Increased rates of bull trout captured in the vicinity of Albeni Falls Dam would be consistent with the hypothesis that bull trout were either entrained (if juveniles were captured) or blocked (if migratory adults were captured) by the dam. We conducted electrofishing relative abundance surveys between Indian Creek (RKM 130.8) and the tailrace of Albeni Falls Dam (RKM 145) in July and August 2003 and compared these data to reservoir-wide surveys conducted from 1988-1990 (summarized in Ashe and Scholz 1992) that used the same electrofishing boat and 10 minute transect method used in 2003.

From 1988-1990, four bull trout were captured in a sample of 47,715 total fish during 216.6 hours of electrofishing effort at randomly selected sites throughout Box Canyon Reservoir. The relative abundance (RA) and catch-per-unit-effort (CPUE) of bull trout in those surveys were respectively 0.008 percent and 0.02 bull trout per hour (Ashe and Scholz 1992). For comparison, in 2003, six bull trout were collected in a sample of 505 total fish during 5.2 hours of electrofishing effort targeted from the tailrace area below Albeni Falls Dam downstream to Indian Creek. The relative abundance and CPUE for bull trout were respectively 1.2 percent and 1.2 bull trout per hour (Geist et al. 2004).

We also collected six additional bull trout during electrofishing surveys that targeted bull trout in 2003. As two bull trout caught in the latter surveys were recaptured fish that had been tagged during the relative abundance surveys, a total of ten different bull trout were collected below Albeni Falls Dam in 2003. All ten were migratory adult fish, 435-722 mm FL. Nine were captured in the vicinity of a culvert on the left (south) bank of the Pend Oreille River one km below Albeni Falls Dam spillway and one was captured at the mouth of Indian Creek. These sites provided cold water refuges for bull trout when the temperature of the Pend Oreille River warmed to a point above the tolerance level for bull trout. For example, during July, when water temperatures in the main river channel were 24-26 °C, temperatures of 15 °C and 18 °C were measured respectively at the mouths of the culvert and Indian Creek.

Although none of the ten bull trout captured in 2003 bore fin clips or PIT tags from upstream sites, it was nevertheless apparent that they most likely originated from above the dam. If the fish were fluvial or adfluvial bull trout that spawned in tributaries of the Pend Oreille River below Albeni Falls Dam, then it is probable they would have sought thermal refuge in their home spawning tributaries similar to the behavior of Middle Fork East River population of bull trout described above.

The capture of so many bull trout below the dam in 2003 was surprising. In view of the fact that few bull trout were caught in previous surveys where effort was distributed farther away from Albeni Falls Dam, the 2003 results (which found bull trout concentrated in the Albeni Falls Dam tailrace) were consistent with the hypothesis that migratory adult bull trout were staging below the dam in a futile attempt to surmount it. To obtain additional information about this possibility, seven adult bull trout captured during the electrofishing surveys were implanted with radio transmitters and released at the culvert to determine their interaction with the dam. Six of these fish made forays between the culvert and the dam during July and were detected approaching the dam by stationary receivers mounted on the dam and directed into the tailrace area. Detection by these receivers indicated that the fish approached to at least within 350-500 meters of the dam and possibly closer. Thus, these data supported the hypothesis that bull trout were staging in the cold water refuge of the culvert and periodically attempting to pass above the dam.

By 8 August, 2003 water levels in the culvert began to recede due to declining surface elevation of Box Canyon Reservoir and eventually prevented access of bull trout to the culvert, forcing them into the warmer waters of the Pend Oreille River. Access into Indian Creek was also blocked at that time. High mortality of transmitter implanted fish occurred during this period. We suspected that poaching may have contributed to mortality of these fish as one transmitter was found buried underneath a rock and a second was found with evidence of tampering (the tubing around the antenna had been stripped off).

Objectives (2004)

In 2004, we continued investigating fish behavior in relation to Albeni Falls Dam. Our objectives were to:

1) Repeat electrofishing surveys to determine if additional bull trout could be detected below Albeni Falls Dam. In addition to sampling during July and August, sampling was also conducted in May and June (when adfluvial migrations of mature adults to home spawning tributaries are known to occur) and in October and November (when post-spawning adults are known to migrate to overwinter sites and emigration of juveniles on their first adfluvial migration out of the Priest River is expected to occur). Thus, our sampling would encompass biologically appropriate times to encounter migrating fish.

2) Evaluate the potential of using the culvert for a trap-and-haul facility as a low cost alternative to passage facilities at the dam. Our 2003 investigations demonstrated that the culvert with cold, spring fed water on the left bank of the river was highly attractive to bull trout by acting as a coldwater refuge for them. We felt that it might be possible to trap bull trout at the culvert and haul them around the dam. We recognized that, at the time bull trout were captured during the summer of 2003, transport around the dam would not have been feasible because the temperature of the Pend Oreille River was above the thermal tolerance for bull trout. Consequently, if the site would prove useful for trapping bull trout, it needed to be demonstrated that bull trout could be captured there at biologically appropriate times for migration (May/June or October/November). In 2004, the site was surveyed at each of these times as well as during the summer.

3) Conduct radio-telemetry investigations with bull trout captured in the tailrace below Albeni Falls Dam. After tagging them with internal radio transmitters, release them above the dam to determine if they migrate upstream (to Lake Pend Oreille or tributaries of the Lake or river above the dam) or downstream (below the dam). If the fish moved upstream after release, especially if they moved into tributaries of the lake or river at biologically appropriate times for spawning, it could be inferred that the fish had been entrained at Albeni Falls Dam, which prevented migration back to home spawning tributaries.

Methods

Study Area

Eastern Washington University and Battelle crews collected bull trout in a 14 km reach of the Pend Oreille River between Indian Creek (RKM 131) and Albeni Falls Dam (RKM 145) (Figure 1). Radio tracking occurred above Albeni Falls Dam on the Pend Oreille River through Lake Pend Oreille, east to Cabinet Gorge Dam (RKM 241), and south to end of Lake Pend Oreille. Tracking included tributary streams known to harbor bull trout: Priest River (including main stem to Outlet Dam on Priest Lake, the East River, and Middle Fork East River); north shore tributaries (Trestle Creek; Pack River main stem and tributaries); East shore tributaries (Granite, Gold, and North Gold creeks); and Clark Fork tributaries (Lightning Creek and tributaries; Johnson and Twin creeks). Lake Pend Oreille has a surface area of 38,362 hectares, 282 km of shoreline, mean depth of 30 m, and a maximum depth of 351 m (Merriam 1975; PBTTAT 1998).

Field Collections

Boat electrofishing, backpack electrofishing, fyke netting, and snorkeling methods were employed to capture bull trout from the Pend Oreille River between Indian Creek, Washington (48.24453 ºN, 117.15051 ºW) and Albeni Falls Dam, Idaho (48.1889015 ºN, 117.18890 ºW) in 2004. Additional sampling was conducted by the Washington Department of Fish and Wildlife, and the Kalispel Indian Tribe from Box Canyon Dam (RKM 55.5) to Indian Creek using boat electrofishing, gill nets, and fyke nets (see Divens 2005). These data were used to compare relative abundance and catch-per-unit-effort (CPUE) from throughout the reservoir with data we collected near the dam.

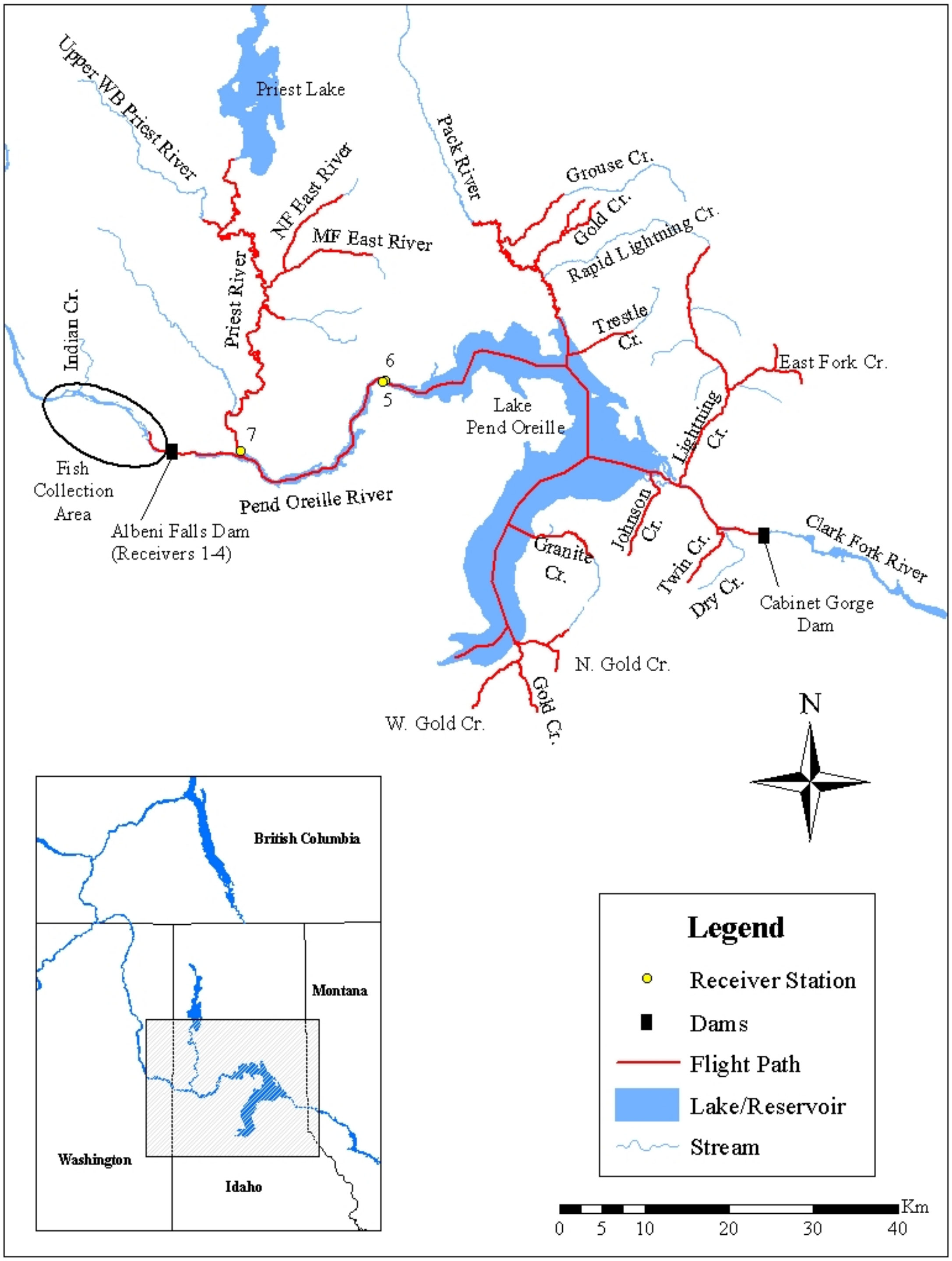

Figure 1. Map describing areas of fisheries surveys (from Indian Creek to below Albeni Falls Dam), stationary receiver locations, and flight path used to track bull trout movements.

Ten minute boat electrofishing surveys (2-4 amps, 250 volts, 120 pps, DC current) were conducted on 10-12 May, 16 June, 22-23 June, 20-21 July, 5 August, 27 October, and 8 November, 2004. A total of 101 sites were electrofished during the survey period. Of these, 74 were used for relative abundance calculations and 27 were bull trout only collections. Transects were sampled during both day and night hours.

Fish were identified using keys of Wydoski and Whitney (1979, 2003). All fish collected were measured to the nearest mm total length (TL), weighed (grams) and released, unless it was a bull trout (see section on Bull Trout Tagging and Relocation below). Tissue samples were collected from bull trout and cutthroat trout by removing a piece of fin with a hole punch. Samples were preserved in 100% ethanol and sent to the Kalispel Tribe to include in their basin wide microsatellite DNA analysis being funded by Bonneville Power Administration (Olson et al. 2004).

Backpack electrofishing was utilized on 5 August in Indian Creek. The survey began at the mouth of the creek and extended 188 m to the culvert, where the creek runs under LeClerc Creek Road. All fish were collected, identified and counted. A sub-sample of each species was measured to the nearest mm TL.

Two fyke nets were deployed on 10 May in an effort to capture bull trout. One net was set near the culvert (48.17683 ºN, 117.01899 ºW) just below Albeni Falls Dam, and the other along the north shore just upstream of the boat launch (48.17704 ºN, 117.01605 ºW). Nets were set for 24 hours, all fish collected were identified, measured and weighed.

Snorkel surveys were conducted in the culvert below Albeni Falls Dam when water elevations permitted at least 15 cm of breathing room. Surveys took place on 20 July and 5 August during both the day and night. Each end of the culvert was blocked using a block net. Surveys were conducted with 2-3 individuals moving in one direction together through the culvert using underwater flashlights to spot fish. After one direction was completed, a sweep the other direction was completed. A seine net was drug through the culvert during the 20 July survey, when water in the culvert was deep. During the 5 August survey the water in the culvert was shallow and dip nets were used to collect fish.

Culvert Analysis

The culvert below Albeni Falls Dam on the south bank was previously suggested as a possible site for a trap and haul location for bull trout (Geist et al. 2004). Cold spring water feeds the culvert from the south side of the culvert, as well as through a hole in the middle of the culvert. The direction of water flow (in or out) in the culvert depended on the elevation of the water in the river. Notes were taken to describe the water flow and depth during each survey. Data was gathered from the US Army Corps of Engineers, Northwestern Division; www.nwd-wc.usace.army.mil to compare water elevation to flow in the culvert. Water temperatures were taken at the surface and bottom of the water at each end of the culvert, and when possible in the middle. A Tidbit temperature data logger was launched and placed at the mouth of the culvert (river side) on 29 July and programmed to take readings every half hour through 5 August 2004. Data on water temperature at Albeni Falls Dam was also gathered from the US Army Corps of Engineers website. Temperatures were compared using a paired T-test ($\alpha = 0.05$).

Bull Trout Tagging and Relocation

Bull trout captured during field collections were placed in a large cooler (142.5 liters) with fresh water. The cooler was aerated with oxygen from a small oxygen cylinder and regulator. Ice was used to maintain ambient river temperatures when needed. The lid was kept closed until the fish stabilized and recovered from the stress of the move. The fish was then anesthetized (70-100 mg L^{-1} MS 222). Once the anesthesia took effect the fish was checked for fin clips and scanned with a PIT tag detector to confirm it had not previously been captured and tagged.

Surgical implantation of the transmitters was completed by experienced surgeons. Procedures used were described by McLeod and Clayton (1997) and Brown et al. (1999). The bull trout was placed in a water soaked foam block that had the middle cut out. The fish was placed dorsal side down, and water was flushed through the gills using an underwater pump connected to a piece of tubing placed in the mouth of the fish. Water was periodically poured over the fishes body during surgery to keep it hydrated. A 2-3 cm longitudinal incision was made 3 cm anterior to the pelvic fins. A Destron-Fearing PIT tag (DF TX 1400BE, 12 mm long, 134.KHz) was placed in the body cavity according to standard protocols (CBFWA 1999). A 16 gauge hypodermic needle was inserted through the body wall to the side and posterior to the incision. The transmitter antenna wire was then inserted through the hollow needle, and the needle removed, leaving the antennae exiting the body wall of the fish. The Lotek digitally encoded radio transmitter (MCFT 3EM, 8.9 g, 5 s pulse interval, 399 d tag life) that operated at a frequency of 148.520 MHz was inserted into the body cavity. The incision was closed using individual sutures spaced at 1-cm intervals that ended in a square knot. Finally, a fungicide was topically applied to the incision. The fish was then placed in an oxygenated cooler with fresh cold water to recover.

The fish was transported by vehicle in an oxygenated cooler to the public boat launch on the east side of the town of Priest River, Idaho 7.5 km above Albeni Falls Dam. Once the fish was completely recovered, it was released into the water at the boat launch, located on the north bank of the Pend Oreille River about 0.5 km downstream of its confluence with the Priest River. This location was selected because it was above Albeni Falls Dam, but far enough downstream that it had the opportunity to swim up Priest River or continue past towards Lake Pend Oreille.

Radio Telemetry Monitoring

Seven radio fixed-ground stations with continuous data loggers, vehicle, and aircraft tracking were the primary techniques used to monitor movements of tagged bull trout in the study area.

Fixed Ground Stations

Seven radio receiving stations were setup in the study area on 27-28 April 2004. Receiver locations and setup were the same as during the 2003 study (Geist et al. 2004). Sites included: Albeni Falls Dam (4 stations), Mudhole Campground on the Priest River (1 station), and the Dover Railroad Bridge (2 stations) approximately 26 km upstream of the Priest River. Each station consisted of a Lotek SRX-400 radio receiver connected to aerial Yagi antennas. The receivers were supplied with either AC or DC (12 volt vehicle batteries) power. Solar panels were used to recharge DC power systems. Beacon tags were used at Albeni Falls Dam and Dover Bridge to monitor receiver status. The beacon tags were programmed to transmit a one minute signal every hour.

Receiver stations 1 and 2 were located on the dam approximately mid river. The stations on the dam were split between up and down river arrays. There were five Yagi antennas pointing upstream and five pointing downstream, which were designed to monitor fish moving past the dam. Due to required maintenance on the dam, the upstream arrays were reduced to one antenna pointing upstream in the middle of the dam on 5 August 2004. Station 3 was located near the forebay above Albeni Falls Dam on a cement bulkhead below the parking lot. The receiver at this station was attached to an antenna pointed south-southwest into the forebay. Station 4 was located on the end of the log chute on the downstream side of the dam and connected to an antenna that pointed out into the tailrace of the powerhouse. Calibration of the four sites in 2003 showed good coverage with a few dead spots immediately upstream and downstream of the powerhouse. The areas of no coverage were small and insignificant compared to the total coverage area (Geist et al. 2004).

Receiver stations 5 and 6 were located on the north and south sides of the Pend Oreille River on the railroad bridge at Dover (Figure 1). Station 5 was located on the north side of the river and Station 6 was on the south side. These stations were designed to cover the entire width of the river, and calibration tests performed in 2003 showed excellent coverage (Geist et al. 2004). Each station was connected to two Yagi antennas that were bolted to trees 5-10 m above the ground. Receivers and batteries were securely locked in large boxes. Burlington Northern right-of-way areas near the railroad were used to access sites.

Receiver station 7 was located at the Mudhole Campground located at the mouth of the Priest River. The receiver was located in the campground sub-station and connected to a Yagi antenna bolted to a tree 10 m high.

All fixed receiver stations were inspected and data downloaded every two weeks between 27 April and 5 November 2004. Data were downloaded using a Lotek Winhost program onto a laptop. Data were saved to a laptop computer and then backed up on a removable thumb drive. After each download, data were examined for active tags, beacon tag signals, and noise. Proper adjustments to the gain were made when necessary. Each station was inspected for damage and repaired if necessary. Beacon and 12 volt batteries were replaced when necessary.

Mobile Tracking

Movements of tagged bull trout were monitored using radio receivers (Lotek SRX 400) connected to a 4-element Yagi antenna from a boat, vehicle, and fixed-wing aircraft. The day after tagged bull trout were released, vehicle and boat surveys of the area were used to locate the bull trout. The receiver was connected to a Yagi antenna and held during boat surveys on the river (7 July). The same method was used in the vehicle, with the antenna held out the window while driving along the river (18, 23, 30 June). We used data gathered from the fixed stations to focus tracking in particular areas. Vehicle tracking from Sandpoint, east to Trestle Creek, then along the creek was completed on 24 July. Vehicle tracking was conducted along Lightning Creek on 31 August.

A Cessna C-182 aircraft chartered from Felts Field Aviation, Spokane, Washington with a single four-element Yagi antenna mounted externally was utilized for aerial tracking. Four aerial surveys of the study area were carried out on 27 July, 30 August, 3 October, and 23 November 2004. Flights were scheduled monthly to focus on pre and post bull trout spawning. A pilot and Eastern Washington University employee flew similar flight plans that were used during the previous year (Geist et al. 2004) (Figure 1).

Flights started at 07:00 and lasted four hours. The route started below Albeni Fall Dam at 305 m above the water surface with the receiver gain set at 75. The plane's path followed the Pend Oreille River upstream from Indian Creek along the center of the river to the outlet of Lake Pend Oreille. The Priest River was monitored from its confluence with the Pend Oreille River up to Outlet Dam, including the East and Middle Fork East rivers. The flight path continued over the west arm of Lake Pend Oreille to the Pack

River. At the mouth of the Pack River the flight path followed the Pack River, and Gold and Grouse creeks. Trestle Creek was then surveyed. The flight path then followed along the center of the East Arm of the Lake to Cabinet Gorge Dam. The flight path then continued up through Lightning, Twin, and Johnson Creek drainages. Next, the flight path went south across Lake Pend Oreille to the south arm and then followed the eastern shoreline (including Granite, North Gold, and Gold creeks). Monitoring then continued west along the southern perimeter of Lake Pend Oreille to the outlet where coverage commenced.

Bull trout encountered during mobile tracking surveys were noted on a map and a position was recorded using a Global Position Positioning (GPS) receiver. Landmarks to distinguish the site were noted. Date, time, weather, and habitat were recorded for each location.

Results

Relative Abundance Surveys

Table 1 provides a synoptic list of fish species collected in the Pend Oreille River main stem. In 2004, a total of 2,113 fish were collected via boat electrofishing in the Pend Oreille River, which represented 22 species, during 12.33 total hours of boat electrofishing (Table 2). Two bull trout were collected during these surveys, representing 0.1% of the relative abundance (Table 2). The catch rate for bull trout was 0.2 fish per hour. One of the bull trout was captured about 2.8 km below the dam on the right bank on 16 June. The other was caught at the mouth of the culvert 1.5 km below the dam on the left bank on 22 June. Other noteworthy captures included two lake trout, two lake whitefish and three kokanee (which were likely washouts from above the dam) and two walleye. Northern pikeminnow (19.1 %) comprised the majority of the relative abundance followed by pumpkinseed (16.7 %).

During non-relative abundance surveys 2,038 fish were observed, with the majority being mountain whitefish (n = 905) (Table 3). One bull trout was observed at the mouth of Indian Creek on 27 October, however it escaped before it could be netted. Two northern pike were also observed (one collected) on 27 October near the boat launch during a non-relative abundance survey.

The two fyke nets captured 94 fish with the majority being yellow perch (24.5 %) and tench (23.4 %). No bull trout were captured (Table 4).

Indian Creek was surveyed on 5 August 2004 using a back-pack electrofisher (20 min effort). Brown trout comprised the majority of the catch (78 %; n = 65) and ranged from 50-150 mm TL. Sculpin (*Cottus* sp.) (18 %; n = 15) and brook trout (*Salvelinus fontinalis*) (3 %; n = 3, 150-200 mm TL) were the other species collected. No bull trout were collected.

Table 1. Synoptic list of fish captured during Pend Oreille River surveys 2004[1].

Family	Species	Scientific Name
Cyprinidae	Peamouth	*Mylocheilus caurinus* (Richardson, 1836)
	Northern pikeminnow	*Ptychocheilus oregonensis* (Richardson, 1836)
	Redside shiner	*Richardsonius balteatus* (Richardson, 1836)
	Tench	*Tinca tinca* (Linnaeus, 1758)
Catostomidae	Longnose sucker	*Catostomus Catostomus* (Forster, 1773)
	Largescale sucker	*Catostomus macrocheilus* Girard, 1856
Ictaluridae	Brown bullhead	*Ameiurus nebulosus* (Lesueur, 1819)
Esocidae	Northern pike	*Esox lucius* Linnaeus, 1758
Salmonidae	Lake whitefish	*Coregonus clupeaformis* (Mitchell, 1818)
	Cutthroat trout	*Oncorhynchus clarki* (Richardson, 1836)
	Rainbow trout	*Oncorhynchus mykiss* (Walbaum, 1792)
	Kokanee	*Oncorhynchus nerka* (Walbaum, 1792)
	Mountain whitefish	*Prosopium williamsoni* (Girard, 1856)
	Brown trout	*Salmo trutta* Linnaeus, 1758
	Bull trout	*Salvelinus confluentus* (Suckley, 1858)
	Lake trout	*Salvelinus namaycush* (Walbaum, 1792)
Centrarchidae	Pumpkinseed	*Lepomis gibbosus* Linnaeus, 1758
	Smallmouth bass	*Micropterus dolomieui* Lacepède, 1802
	Largemouth bass	*Micropterus salmoides* (Lacepède, 1802)
	Black crappie	*Pomoxis nigromaculatus* (Lesueur, 1829)
Percidae	Yellow perch	*Perca flavescens* (Mitchell, 1814)
	Walleye	*Sander vitreus* (Mitchell, 1818)

[1]Slimy sculpin, *Cottus cognatus*, were not collected in 2004, but present in 2003

Table 2. Electrofishing relative abundance (RA), catch-per-unit-effort (CPUE), mean total length, and length range of fish captured in the Pend Oreille River, 2004 (effort = 12.33 hrs).

Species	N	RA (%)	CPUE (fish/hr)	Mean TL (mm)	TL range (mm)
Peamouth	172	8.14	13.9	265	162-357
Northern pikeminnow	404	19.12	32.8	254	91-640
Redside shiner	3	0.14	0.2	73	57-97
Tench	85	4.02	6.9	296	125-572
Longnose sucker	79	3.74	6.4	332	44-485
Largescale sucker	248	11.69	20.0	391	115-546
Brown bullhead	15	0.71	1.2	255	160-315
Cutthroat trout	5	0.24	0.4	291	165-372
Lake whitefish	2	0.09	0.2	460	410-510
Rainbow trout	7	0.33	0.6	256	132-421
Kokanee	3	0.14	0.2	196	186-208
Mountain whitefish	183	8.66	14.8	281	181-372
Brown trout	68	3.22	5.5	359	111-592
Bull trout	2	0.09	0.2	647	640-653
Lake trout	2	0.09	0.2	532	478-585
Pumpkinseed	352	16.66	28.5	112	12-155
Smallmouth bass	60	2.84	4.9	220	90-373
Largemouth bass	86	4.07	7.0	187	64-534
Black crappie	100	4.73	8.1	136	30-248
Yellow perch	235	11.12	19.1	154	71-223
Walleye	2	0.09	0.2	559	551-566
Grand Total	2,113	100.0	171.0		

Table 3. Estimated number of fish observed during non-relative abundance surveys on 27 October and 8 November 2004.

Species	Number of fish observed
Peamouth	241
Northern pikeminnow	101
Tench	18
Sucker species	256
Brown bullhead	1
Rainbow trout	1
Mountain whitefish	905
Brown trout	8
Bull trout	1
Northern pike	2
Pumpkinseed	188
Smallmouth bass	49
Largemouth bass	5
Yellow perch	262
Grand Total	2,038

Table 4. Relative abundance (RA), catch-per-unit-effort (CPUE) on 2 net nights, mean total length, and size range of fish captured in fyke nets set in 2004.

Species	N	RA (%)	CPUE (fish/net night)	Mean length (mm)	Size range (mm)
Peamouth	1	1.06	0.5	290	290
Tench	22	23.40	11.0	362	194-430
Longnose sucker	1	1.06	0.5	374	374
Largescale sucker	10	10.64	5.0	436	411-469
Brown bullhead	16	17.02	8.0	288	240-331
Mountain whitefish	7	7.45	3.5	274	255-311
Pumpkinseed	11	11.70	5.5	136	111-270
Smallmouth bass	2	2.13	1.0	298	260-335
Black crappie	1	1.06	0.5	177	177
Yellow perch	23	24.47	11.5	200	152-230
Grand Total	94	100.0	47.0		

Culvert and Water Temperature Analysis

Particular attention was paid to the culvert area because the majority of bull trout captured in 2003 were found inside the culvert, which provided a cold water refuge (Geist et al. 2004). Sampling started earlier in 2004 (10 May) compared to 2003 (8 July). Higher water elevation in 2004 (Figure 2) postponed snorkeling until 20 July, which was 12 days later than 2003 (Geist et al. 2004). It was found that the elevation of the river determines if river water is flowing into the culvert or spring water is flowing out of the culvert. Comparing reservoir elevation in 2003 and 2004 we were able to determine that if the water is above 2,035 ft (620.3 m) the water flows into the culvert and out the far side (Figure 3). This caused the cold spring water to flow out the far side into a wetland (Figure 3). When the river elevation dropped below 2,035 ft the water flowed out of the culvert into the river, which allowed the cold water to enter the river and makes the entire length of the culvert a cold water refuge (Figure 4).

Spring water leaked into the culvert through small holes throughout the length with a large influx near the middle at approximately 1 gallon per minute. There was also a spring located at the far end of the culvert (wetland side) on the west bank that drained immediately into the creek. Spring water was consistently measured at 9 ºC.

Bull trout preferences are typically below 15 ºC (Fraley and Shepard 1989; Baxter and McPhail 1996). Water temperatures exceeded 15 ºC for 102 days during 2004, starting on 25 June (17.2 ºC) and lasting until 5 October (15.0 ºC) (Figure 5). Temperatures taken at the mouth of the culvert with a hand held thermometer were relatively similar to reservoir temperatures (Figure 5). However, the tidbit data logger temperature recordings inside the culvert were significantly different ($P < 0.05$) from reservoir temperatures. Between 29 July and 5 August, the reservoir mean temperature was 22.6 ºC and the culvert temperature was 11.6 ºC.

Figure 2. Photographs of the culvert below Albeni Falls Dam on the Pend Oreille River side. a) Culvert underwater in spring, 10 May 2004, b) Culvert out of water, 20 July 2004.

Figure 3. Pictures of the culvert and the wetland area on the south side of the culvert when the water elevation was 2,035 ft. in the Pend Oreille River below Albeni Falls Dam.

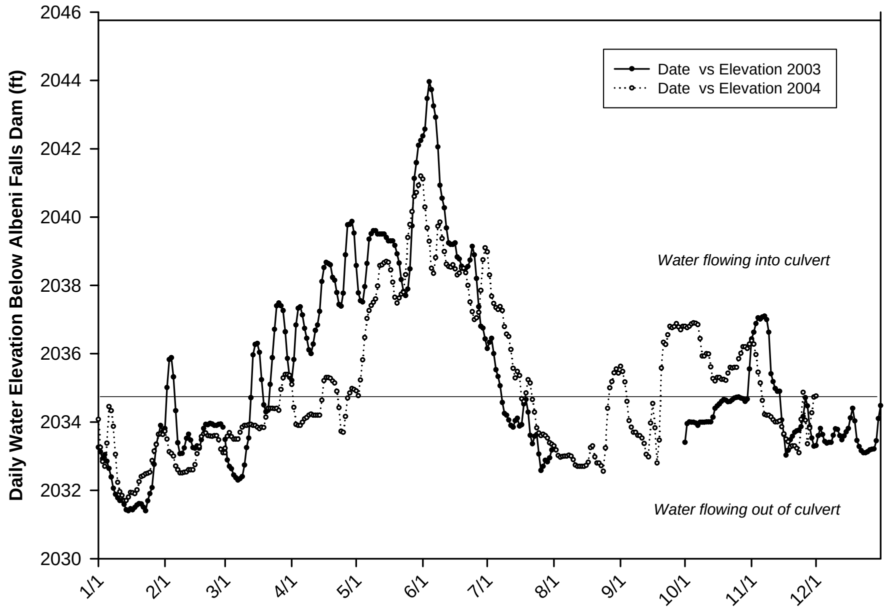

Figure 4. Water elevation during 2003 and 2004 below Albeni Falls Dam. Line at 2,035 feet indicates change in water flow in or out of the culvert. Data gathered from US Army Corps of Engineers, Northwestern Division; www.nwd-wc.usace.army.mil.

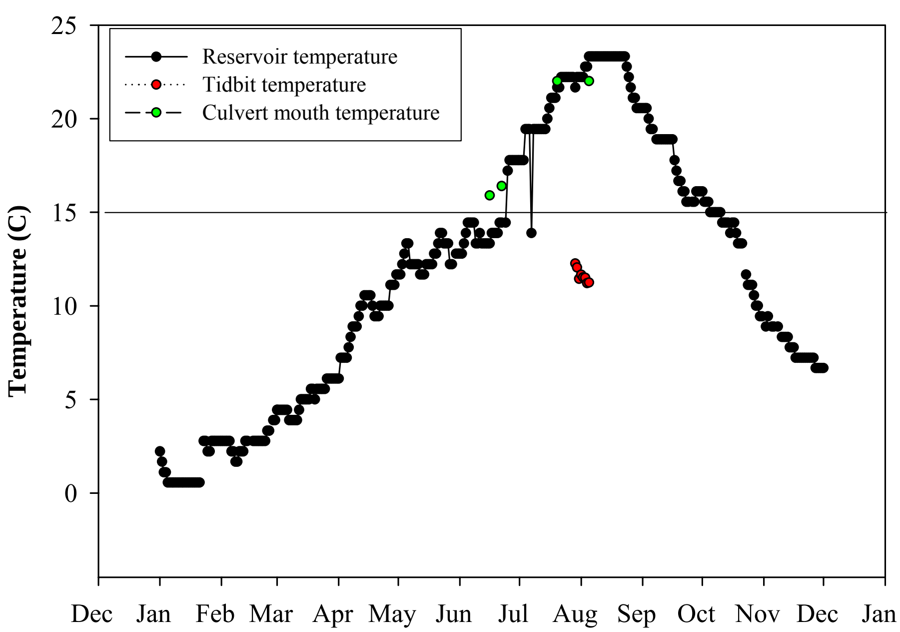

Figure 5. Temperature below Albeni Falls Dam during 2004. Data gathered from USACE, Northwestern Division; www.nwd-wc.usace.army.mil. Solid line indicates bull trout upper preference temperature (15 ºC).

Bull Trout Movements

Two bull trout were captured during electrofishing surveys. The first fish (Table 5) was captured near the boat launch at the Newport bridge on 16 June, when water temperatures were 14.3 ºC. The fish was 653 mm TL (627 fork length) and weighed 3,600 g. This fish was implanted with a radio tag on frequency 148.520 coded 110. The second fish (Table 5) was captured at the mouth of the culvert on 22 June when water temperatures 16.9 ºC. This fish was 640 mm TL and weighed 1,000 g. This fish was implanted with the same radio tag frequency but coded 103. Both fish were successfully implanted with radio tags and in excellent condition when released above Albeni Falls Dam at the boat launch on the east side of the town of Priest River. River temperature at the release site was 13.9 °C when the first fish was released and 14.4 °C when the second fish was released. Tracking by boat and vehicle began within 24 hrs of release.

Table 5. Capture location, radio tag numbers, and PIT tag numbers used for the two bull trout captured in 2004.

Bull trout	Capture Location	Lat and Long.	Radio Tag	PIT Tag
1	Near boat launch	48.18168, 117.02760	148.520 (code 110)	3D91BF1A907 1E
2	Culvert	48.17731, 117.02760	148.520 (code 103)	3D91BF198CBBB

Fish 110. Fish 110 was released on 02:00 on 17 June from the Priest River boat launch. This fish was not detected during boat and vehicle surveys conducted in the Pend Oreille River near Albeni Falls Dam and Priest River confluence the day after release. Fish 110 was detected by the stationary receivers at the Dover Bridge site (27.2 km from the release site), 21.5 hrs after its release, migrating upstream towards Lake Pend Oreille (Table 6). Vehicle tracking around Lake Pend Oreille and up Trestle Creek did not detect the fish. The first aerial flight on 27 July did not detect any fish. However, during the second flight on 30 August, fish 110 was detected in Lightning Creek just below the east and west branch (48.22769 ºN, 116.11594 ºW) at 09:55 (Table 7) (Figure 6). The fish had traveled 72.4 km from the release site to the mouth of Lightning Creek, then 12.6 km up the creek for a total 85 km trip. Vehicle tracking was attempted to find this fish, but the washed out bridge over the creek was too deep to ford in a truck. Both subsequent flights (3 October and 23 November) did not detect either of the bull trout. The fish was

not detected again. Stationary receivers were downloaded through 5 November and had not detected fish 110 again (Table 6). This fish was presumed to be residing in Lake Pend Oreille.

Fish 103. Fish 103 was released at 03:00 on 23 June from the Priest River boat launch. This fish was not detected during boat and vehicle surveys the following the day. This fish passed Dover Bridge 14.5 hrs after its initial release from Priest River boat launch (Table 6). Fish 103 presumably entered Lake Pend Oreille stayed there because it was not detected again during vehicle or aerial flights. As of 5 November, when stationary receivers were removed, fish 103 had not traveled back downstream towards Albeni Falls Dam (Table 7) (Figure 7).

Both fish migrated quickly to Lake Pend Oreille. Boat tracking was not attempted in Lake Pend Oreille because radio tags usually are not detectable in deep lakes and aerial flights became our primary focus. Four aerial flights were budgeted; therefore we tried to spread flights out monthly in an attempt to detect both fish during the spawning season.

Table 6. Dates when radio receivers were downloaded, mobile and aerial surveys were conducted, and when bull trout were detected, 2004 (noted as transmitter codes).

Stationary Receivers Download	Bull Trout Detected	Vehicle and Boat Tracking	Bull Trout Detected	Aerial Tracking Flights	Bull Trout Detected
23 June	110[1]	18 June	--	27 July	--
30 June	103[1]	23 June	--	30 August	110
7 July	--	30 June	--	3 October	--
14 July	--	7 July (boat)	--	23 November	--
21 July	--	24 July	--		
6 August	--	31 August	--		
17 August	--				
31 August	--				
15 September	--				
1 October	--				
20 October	--				
30 October	--				
5 November	--				

[1] Detected by stationary receivers at Dover Railroad bridge.

Table 7. Time scale of bull trout capture, release and subsequent detection above Albeni Falls Dam, 2004.

Capture Date and Time	Release Date and Time	Dover Bridge Detection	Next Detection
16 June at 23:50	17 June at 02:00	18 June 11:24-12:09	30 August 09:55 in Lightning Creek
22 June at 23:45	23 June at 03:00	23 June 17:26-17:52	none

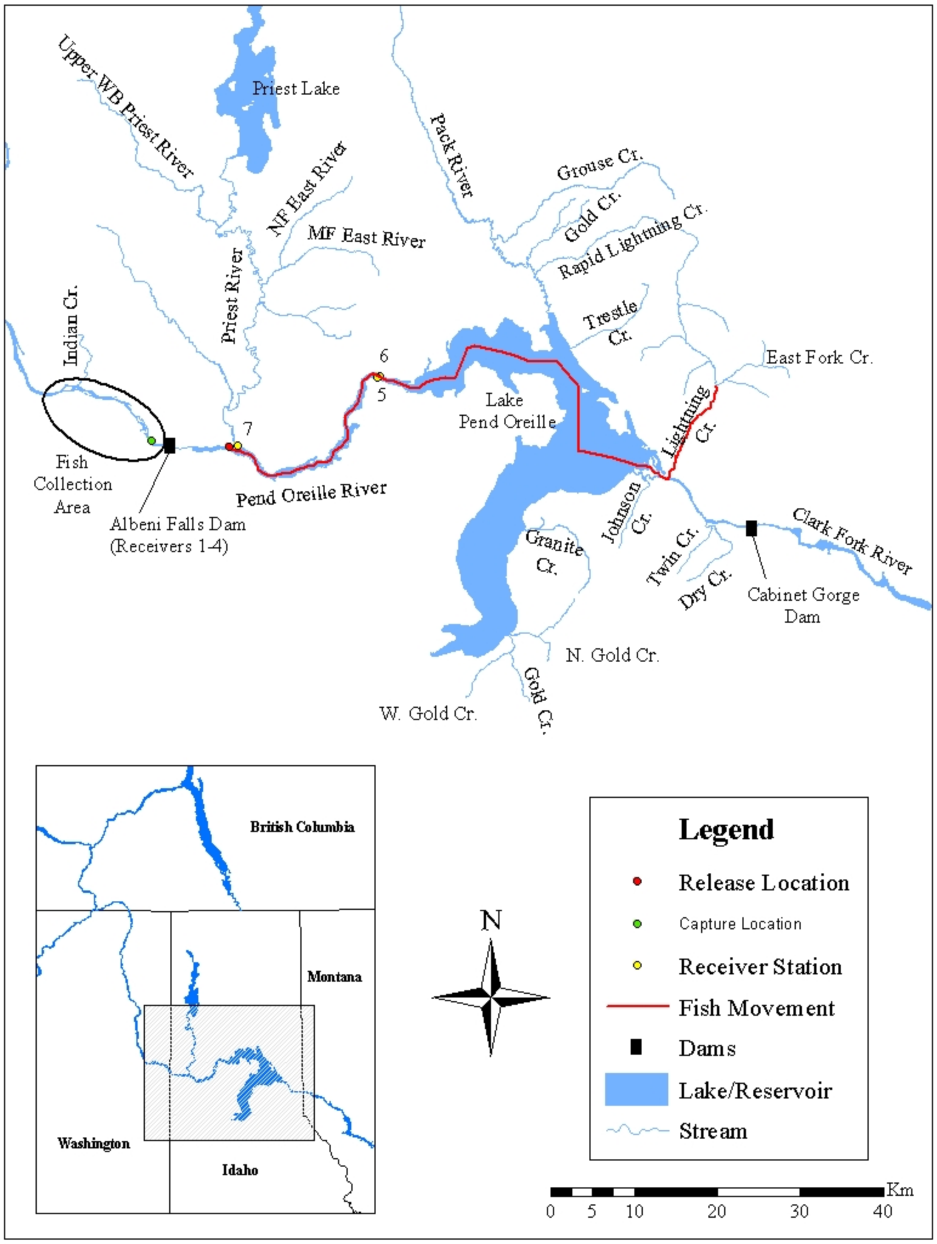

Figure 6. Movement of bull trout 110 from the release site above Albeni Falls Dam, past Dover Bridge, to Lightning Creek.

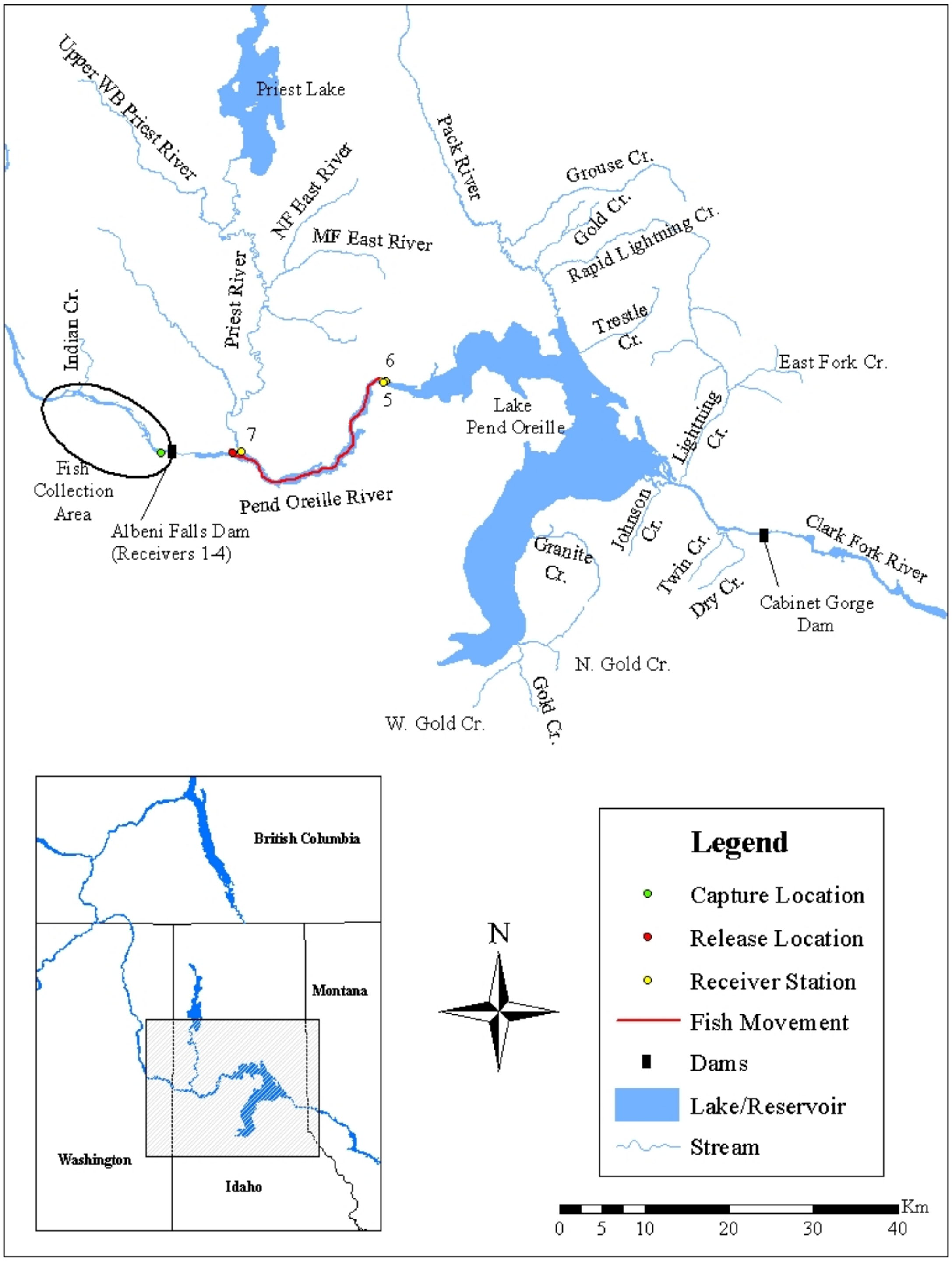

Figure 7. Movement of bull trout 103 from the release site above Albeni Falls Dam, past Dover Bridge.

Discussion

Two bull trout were captured in 2004 immediately downstream of the Albeni Falls Dam tailrace. Two lake trout, two lake whitefish, and three kokanee were also recorded. These three non-indigenous species are common in Lake Pend Oreille, but not in the Pend Oreille River below Albeni Falls Dam.

In 2004, WDFW and the Kalispel Tribe conducted a survey of Box Canyon Reservoir between Box Canyon Dam and Albeni Falls Dam (Divens 2005). During the survey a total of 126 electrofishing sites (each 0.5 km in length), 64 fyke net sites, and 56 gill net sites were sampled at randomly selected locations over a four-day interval in May. Our surveys in May were coordinated with this effort. We were assigned the reservoir section between Indian Creek and Albeni Falls Dam. No gill nets were set in this area to avoid killing bull trout. During the reservoir-wide survey a total of 15,525 fish were captured, including 11,129 in 20.6 hrs of electrofishing, 2,964 by fyke nets, and 1,432 by gill nets (Divens 2005). Two additional reservoir-wide surveys were made by the Kalispel Tribe Department of Natural Resources (KNRD) in 2004, in July, August and October. Survey sites were located between Indian Creek and Box Canyon Dam. During the survey a total of 13 randomly selected electrofishing site, four fyke net sites and 15 gill net sites were sampled between 19 July and 18 August (Jason Conner, KNRD, pers. comm.). During the October survey 16 randomly selected electrofishing sites, four fyke net sites and eight gill net sites were sampled from 18 to 27 October (J. Conner, ibid). These surveys sampled totals of 2,001 and 1,527 fish respectively. No bull trout, lake trout, lake whitefish, or kokanee were sampled in any of these surveys, other than those collected by us in the upper reach of the reservoir below Albeni Falls Dam.

Bull trout, lake trout, lake whitefish, and kokanee were collected only in the 14 km segment between Indian Creek and Albeni Falls Dam. In fact, all of the individuals of each species were collected upstream of the U.S. Highway 2 bridge (i.e., in the tailrace area). Therefore, we inferred that their presence below the dam was related to either entrainment or volitional adfluvial/fluvial migration.

Bull trout collected below the dam may have been entrained below the dam through the water intake structure or “elected” to make a volitional fluvial/adfluvial migration over or through the dam. One possible interpretation is that these individuals represent “sink” fish resulting from a large metapopulation above the dam. “Sink” fish usually occur above the impassable falls. After leaving their source population and migrating over the falls, they are unable to return to spawn in their natal stream and contribute to establishment of new spawning populations or increasing genetic diversity of populations already established below the barrier falls. However, this was probably not historically the case at Albeni Falls because the falls was not a barrier to fish migration (Gilbert and Evermann 1895) and trout (species not identified) were observed “to pass freely up the falls” (Rathbun 1895). Data collected during the present study were consistent with the hypothesis that bull trout congregating below the dam were “electing” to try to go back over the dam but were being blocked. The central issue was not related to the reasons why bull trout were below the dam but rather that the dam appeared to block their volitional upstream migrations.

Neither bull trout captured in 2004 bore fin clips or PIT tags indicating they were from tributaries of Priest River or Lake Pend Oreille. However, it was apparent that these two fish most likely originated from above the dam. If the fish were from fluvial or adfluvial populations that spawned in tributaries of the Pend Oreille River below Albeni Falls Dam, then it is probable they would have sought thermal refuge in their home spawning tributary. Bennett and Garrett (1994) found that brown trout (*Salmo trutta*), another fall spawning species which is more tolerant of warm water than bull trout, moved into spawning tributaries of Box Canyon reservoir well in advance of spawning season. They typically entered tributaries in May and June probably to avoid the warm temperatures of the Pend Oreille River. Therefore, it seems likely that less tolerant bull trout would have exhibited similar behavior had they originated in a tributary below the dam.

Moreover, there is evidence that adfluvial migrations of bull trout into tributaries of the Box Canyon reach of the Pend Oreille River no longer occur or else are an exceedingly rare event. The Kalispel Tribe monitored upstream/downstream migration traps in 12 tributaries between 1997 and 2000 (Scott 1999; Lockwood et al. 2001). Three tributaries were monitored for four years, five for three years, one for two years, and four for one year. No juvenile or post-spawning adult bull trout were captured migrating downstream in any of the traps. Only one adult bull trout was captured migrating upstream (at Indian Creek in September of 1989) and that fish bore a fin clip indicating that it had been released in either Lightning or Trestle Creek, a tributary of Lake Pend Oreille (Lockwood et al. 2001). From our cursory inspection of Indian Creek, there appeared to be little pool habitat that would hold bull trout. Bull trout entering this stream may be attracted by the cold water refuge it offered, rather than using it as a home spawning tributary. These observations are consistent with the hypothesis that bull trout congregating below Albeni Falls Dam are not "sink" fish resulting from a metapopulation above the dam because they do not appear to be seeking out new tributaries in which to spawn. The efficacy of migration traps for capturing bull trout was not determined, so it is possible that if bull trout are trap shy, not many would be expected to be caught. However, the traps were effective in sampling adfluvial brown trout, westslope cutthroat (*Oncorhynchus clarki lewisi*), and other salmonids (Scott 1999; Lockwood et al. 2001).

Between 1987-2002, numerous fish surveys were conducted throughout (or in portions) of Box Canyon Reservoir (Barber et al. 1989a, 1989b,1989c, 1990; Ashe 1991; Ashe et al. 1991, 1991b; Bennett and Liter 1991; Clark 1991; Ashe and Scholz 1992; Skillingstad 1993; Skillingstad et al. 1993; Bennett and Garrett 1994; KNRD and WDFW 1996, 1997, 1998; Scholz 1998; Anderson 2000, 2002; Lockwood et al. 2001; Anderson and Olson 2003; Conner et al. 2003a, 2003b). A summary of each survey is presented in Appendix 1. Collectively these surveys captured a total 95,550 fish, of which only seven were bull trout. When the surveys accomplished during 2003 (Geist et al. 2004) and 2004 (Divens 2005; J. Conner, KNRD, pers. comm.; this report) were added, the total number of fish captured increased to 118,321, with a total of 19 bull trout. The majority of the bull trout (n=12 of 19) were captured during surveys conducted in 2003 and 2004 that targeted the 14 km reach between Indian Creek and Albeni Falls Dam. Reservoir-wide surveys and surveys conducted in the middle of the reservoir near the Kalispel Indian Reservation produced low CPUE for bull trout (0.0-0.02 bull trout per hour), whereas those that targeted the head of the reservoir near the dam produced higher CPUE for bull trout (0.2-

1.2 bull trout per hour). These data suggested that bull trout are not uniformly distributed throughout the reservoir. Rather they appear to be concentrated in the tailrace area below Albeni Falls Dam. Taken together, the correspondence between these various observations increased our confidence that all or most of the bull trout we collected below Albeni Falls Dam in 2003 (n = 10) and 2004 (n = 2) originated from above the dam.

The behavior of two bull trout captured below and transplanted above Albeni Falls Dam in June 2004 provided the strongest support for the hypothesis that these fish had originated from tributaries above the dam. Instead of dropping back down below the dam, both radio-tagged bull trout migrated rapidly from their release point (near Priest River) into Lake Pend Oreille (a distance of approximately 18 km) within 14.5-21.5 hours after release. One of these fish was detected in Lightning Creek, a spawning tributary on the Clark Fork arm of Lake Pend Oreille, 85 km from the fish's release point, on 30 August and was presumed to have spawned there. This fish was not detected on 3 October and was presumed to have returned to Lake Pend Oreille. The second fish apparently did not spawn in 2004 as we did not detect it in any tributary. However, it was possible that the fish entered, spawned and left a tributary between 30 August and 3 October. IDFG maintained a weir with a remote PIT tag detector monitoring system in Trestle Creek during the 2004 spawning season. Additionally, IDFG biologists examined a sample of mature bull trout in other spawning tributaries with a hand-held PIT tag detector. IDFG biologist Chris Downs interrogated the IDFG data base for our PIT tags but did not find a record of either one (C. Downs, pers. comm., 11 January 2005). We presume that at the time of our last air flight (23 November 2004), both fish were residing in Lake Pend Oreille.

The two bull trout were released at 02:00 – 03:00. Mobile tracking surveys by boat in the vicinity of the release site the following morning did not encounter any bull trout, suggesting that they traveled quickly away at night. Nocturnal migration of adult bull trout was also reported in the Flathead (Block 1955; Shepard et al. 1984; Fraley and Shepard 1989) and Blackfoot (Swanberg 1997a) rivers, Montana.

Mature adfluvial bull trout were previously shown to migrate from Lake Pend Oreille, into Lightning Creek at two different times. A segment of the population entered in May or June (Anderson 1971), while a second pulse occurred in August or September (Pratt 1985; Pratt and Huston 1993).

In hindsight, bull trout should have been tracked continuously for the first 24-48 hours of release. In 2004, both radio-implanted fish swam the entire length of the Pend Oreille River and entered Lake Pend Oreille within the first 24 hours after release and only one was heard following this because of attenuation of radio-transmitters in the deep water of the lake. Use of combined acoustic and radio-telemetry transmitter (CART by Lotek) would have allowed for detection of fish in the lake via ultrasonic signals. This may have enabled us to better determine the timing and locations of entry into spawning tributaries. However, this type of effort was not possible given the study's scope and resources.

Upstream movement of bull trout after transport above a dam was not unprecedented (Fernet and O'Neil 1997; Swanberg 1997b; Schmetterling 2003). For example, when Swanberg (1997b) transported four fluvial bull trout above Milltown Dam (located on the Clark Fork River near Missoula, Montana), he found that two fish dropped back below the dam; but the other two traveled upstream distances of 40 and 130 km to spawn in Rock Creek, where addition of these two fish may have contributed meaningful genetic information to a depressed population that constructed 160 redds during that same year. Swanberg concluded that these results suggested that Milltown Dam blocks migration of fluvial bull trout in the upper Clark Fork River and that transporting fish upstream can enhance populations. Schmetterling (2003) radio tracked 14 bull trout transported above Milltown Dam in 2000 and 2001. He found that 13 of these fish migrated distances of 47 – 136.9 km upstream into Rock Creek or tributaries of the Big Blackfoot River. Schmetterling concluded that augmentation of streams with chronically depressed spawning populations ($n \leq 50$) by even a few transported individuals would represent a significant genetic contribution.

Fewer bull trout were captured in 2004 ($n = 2$) than in 2003 ($n = 10$), even though more electrofishing effort was expended in 2004 (12.33 hours) than in 2003 (5.3 hours); the

CPUE was 0.2 bull trout per hour in 2004 (based on 2 fish caught during relative abundance surveys) compared to 1.2 bull trout per hour in 2003 (based on 6 fish caught during relative abundance surveys. Four possibilities could potentially account for these results:

1. Similar numbers of bull trout were entrained or elected to move below the dam in both years of the study but due to random chance more were collected in the first year than the second year.
2. Bull trout collected in 2003 may have included individuals that were entrained or elected to move below the dam over a period of several years whereas those collected in 2004 represented individuals that entrained after 2003 collections were made (about one year);
3. More bull trout were entrained or elected to move below the dam in 2003 than 2004 because of fluctuations in water discharge; and/or
4. The culvert was more attractive to bull trout in the first year of the study than the second year.

It is unclear if CPUE of 0.2 (2004) and 1.2 (2003) bull trout per hour (a six-fold difference) represents a significant difference as both rates were much higher than the CPUE observed over the entire reservoir or middle portions of the reservoir (0.0-0.02 bull trout per hour), a 10-fold or greater difference.

There is a possibility that the difference in numbers of bull trout collected was due to random chance. The tailrace area below Albeni Falls Dam was difficult to sample by electrofishing because the depth of water in the channel was about 3-7 meters across most of its cross sectional profile, i.e., deeper than could be effectively electrofished. Adult bull trout prefer holding areas with cover (Goetz 1988; McPhail and Baxter 1996), and numerous stumps, pilings and large woody debris in deep water provided excellent cover for bull trout. This cover would further decrease catch rates using electrofishing. However, while we acknowledge that these difficulties would preclude obtaining an accurate estimate of the actual number of bull trout entrained in any given year, we assume that higher effort would yield a higher catch. If sampling methods are kept uniform and sampling effort is increased than more fish should be captured in the year with increased effort. In 2004, we expended 2.3 times as much effort as in 2003 to catch 1/6th the number of bull trout. Thus, the possibility that these results occurred by random chance seems remote, although more than two years of data is needed before random chance is eliminated as a possible reason for the differences in catch rates between the two years.

It is possible that more bull trout were collected in 2003 than 2004 because they represented holdovers from several years of washouts from above the dam. This possibility seems less likely than other alternatives because the late summer temperature of Pend Oreille River is above the thermal tolerance of bull trout. In 2003, most of the bull trout we tracked lived for several weeks, making forays between the coldwater refuge in the culvert and the dam. When the surface elevation of Box Canyon Reservoir receded in August, bull trout access into the culvert (water temperature = 11.8 – 13.8 °C) was blocked. After being forced into the warm (23 – 24 °C) waters of the Pend Oreille River, they died shortly thereafter. We attributed this mortality to temperature shock and forcing bull trout to occupy waters with lethal temperatures (EPA 1997). (However, at least two bull trout in 2003 appeared to be caught by poachers – see Geist et al. 2004). Assuming that this scenario repeats itself annually, the accumulation of fish over several successive years would not be expected. Note that it does not seem likely that bull trout from above the dam entered other Pend Oreille tributaries (except maybe Indian Creek) to escape warm water in the Pend Oreille River because the Kalispel Tribe did not catch any (except in Indian Creek) while monitoring migration traps on most of the major tributaries of the reservoir over four years (Lockwood et al. 2001).

The hypothesis that the number of bull trout collected below the dam was positively related to increased discharge was weakly supported. Discharge and bull trout capture were both higher in 2003 than 2004. The mean annual discharge of the Pend Oreille River at the gauge below Albeni Falls Dam in 2003 was 24.2 KCFS and the maximum discharge that year was 67.8 KCFS. In 2004, these values were respectively 20.5 KCFS and 51.9 KCFS. The mean discharge was 98.3 percent in 2003 and 83.3 percent in 2004 of the mean discharge (24.6 KCFS) over the period of record (1960-2004). The peak discharge was 49.1 percent in 2003 and 37.5 percent in 2004 of the peak discharge (138.2 KCFS) over the period of record (1960-2004). Thus, although there was a difference in discharge between 2003 and 2004, it was a subtle difference in relation to discharge measured over the period of record and we were uncertain if this would be a sufficient difference to account for the large difference in number of bull trout each year. Additional sampling would need to be accomplished in order to determine if the number of fish found below the dam increases with increasing discharge. Regression analysis could then be performed to test this hypothesis. It would be particularly important to conduct a survey (or surveys) below the dam during a year (or years) when the mean annual discharge is higher than the mean annual discharge for the period of record, and the maximum discharge is greater than 65 percent that of the maximum discharge over the period of record. Because river discharge was relatively low (below average for the period of record) in both years of our study, the fish we recovered might be a minimum estimation of entrainment or volitional movement downstream. We suspect that the numbers could be higher in years with above average discharge.

There was also a difference in the attractiveness of the culvert for bull trout in 2003 and 2004. In 2003, cold water began flowing out of the culvert on 5 July, about 15 days earlier than in 2004 (refer to Figure 4). The shorter duration of cold water flowing into the river during 2004 may have reduced the attractiveness of bull trout to the culvert that year. Only one bull trout was captured at the culvert in 2004 compared to nine in 2003 when cold water was flowing out. Electrofishing encounters with bull trout were likely reduced in 2004 because they were not concentrated at one location like they were in 2003. However, even after cold water began flowing out of the culvert into the river in 2004 no bull trout were captured there, perhaps indicating that fewer bull trout were present in the vicinity of the dam in 2004 than 2003.

Our evaluation of the culvert as a possible trap-and-haul collection site for bull trout passage around the dam suggested it would be of limited value for that purpose. In 2004, river water flowed into the culvert between approximately 1 May and 15 July, and approximately 19 September to 5 November (Figure 4). These periods coincide with the biologically appropriate time for transporting bull trout because their physiology and behavior are keyed for migration at these times as noted in Appendix 1. For example, radio-tracking studies (Dupont and Horner 2004; Geist et al. 2004) revealed that adult bull trout spawning in the Middle Fork East River made migrations to and from spawning tributaries at these times.

During the two periods when river water flowed into the culvert, water temperatures in the Pend Oreille River ranged from about 10-15 °C, i.e., close to the 10-12 °C thermal optimum for bull trout migration determined by EPA (1997). These times would have been ideal to trap and haul bull trout around the dam because thermal stress would be minimal. By the time cold spring water (9 °C) began flowing out of the culvert into the Pend Oreille River in the mid July, water temperatures in the river had risen above 18°C, which approached the thermal tolerance of bull trout. Removing fish attracted to the culvert at that time and transporting them around the dam would place them under severe thermal stress and reduce the probability that they would make a successful upstream migration.

There appears to be no other good collection site for bull trout below the dam in spring and fall, so the focus of fish passage should be at the dam as it seems likely that salmonids will be attracted to the flow there. We suggest that the log chute (north side of the spillway) might be an appropriate location to establish a trap-and-haul passage facility for bull trout. Advantages of this site include:

1. The small embayment (indentation along the shoreline) between the powerhouse and spillway that the log chute drains into was attractive to fish. Although no bull trout were captured there during our electrofishing surveys, a number of salmonids, including a lake trout, cutthroat trout, rainbow trout and several brown trout and mountain whitefish were. Apparently, fish used this spot as a resting area between the turbulent flows of the spillway and powerhouse channels. Addition of flow from the log chute could potentially be attractive to fish congregated in this area. Bull trout swimming performance under different water temperatures (e.g., Mesa et al. 2003) should be considered when a fish passage facility is designed.

2. The site is well protected from vandalism, requiring USACE permission to enter through gated access points.

Construction of a trap-and-haul facility at the log chute would probably be less expensive than retrofitting it into a fish ladder. We are uncertain about the amount of entrainment from Lake Pend Oreille and/or Priest Lake systems that occurs at Albeni Falls Dam and, hence, the number of migratory fish that might be expected to pass upstream during spawning migrations. Also, there is currently no plan formulated to restore fluvial or adfluvial bull trout in Box Canyon Reservoir reach of the Pend Oreille River where they appear to be functionally extirpated (except, perhaps in LeClerc Creek; refer to supporting material in Appendix 1), so we do not know the number of bull trout from home streams below the dam that might be expected to migrate upstream seeking a cold water refuge in Lake Pend Oreille. It seems reasonable and prudent that the lowest cost alternative for restoring fish passage be utilized until the need for it is better quantified. On the other hand, some form of pilot passage seems necessary to avoid risks associated with underestimating the degree to which loss of migratory bull trout from tributaries above the dam may be occurring. Additionally, the passage facility would provide a way to collect better information about entrainment.

Although our study did not document the extent of entrainment at Albeni Falls Dam, there are some indications that the number of fish entrained was low. Since 1998, 1,917 adult bull trout and 1,340 juvenile bull trout have been PIT tagged in tributaries of Lake Pend Oreille or Clark Fork River below Cabinet Gorge Dam (C. Downs, IDFG, pers. comm.). All but 74 of these were marked since 2000. An additional 853 adult bull trout in East Fork Lightning Creek, Grouse Creek, Gold Creek and Trestle Creek were marked with adipose fin clips in 2000 (Downs et al. 2003). Additionally, we marked 130 juveniles in the Middle Fork East River with PIT tags, some of which would likely emigrate in 2004 (Geist et al. 2004). None of these marked fish were caught below the dam in 2003 or 2004.

In 2002, 600 bull trout were PIT tagged in tributaries of Lake Pend Oreille (C. Downs, IDFG, pers. comm.). Assuming an annual mortality rate of 50 percent, 300 of these fish should have remained in the population in 2003, when spawning escapement into tributaries of Lake Pend Oreille was estimated at 1,786 – 2,590 adults and spawning escapement into the Middle Fork East River (Priest River drainage) was estimated at 53 – 77 adults, for a total spawning escapement between Albeni Falls and Cabinet Gorge Dams of 1,893 – 2,667 adults. Tagged fish accounted for 11 – 16 percent of the adult population. This is a conservative estimate of number of marked fish in the population because it did not account for fish marked with PIT tags or fin clips in previous years that might still be in the population. The mortality projected for PIT tagged fish was based on Pratt (1985) and Pratt and Huston‘s (1993) observation that total annual mortality of bull trout in Lake Pend Oreille ranged from 45 – 88 percent, which included legal harvest at the time those estimates were made. We reasoned that since harvest is no longer permitted, current mortality would be at the lower end of their range.

Assuming that one percent of this population entrained or volitionally migrated below Albeni Falls Dam, a total of 19 – 27 adult bull trout should have been available for capture below the dam in 2003, of which 3 should have been marked. If five percent of this population entrained or volitionally migrated below Albeni Falls Dam, a total of 95 – 133 adult bull trout should have been available for capture below the dam in 2003, of which 15 should have been marked. These calculations assumed that marked and unmarked fish entrained or volitionally migrated below the dam at equal rates as we had no reason to suspect otherwise. If 95 – 133 bull trout had been present in the study area below Albeni Falls Dam in 2003, we should have seen evidence of more bull trout than the ten we collected. Also, one marked bull trout should have been present for every 6 – 9 unmarked fish at either low (1%) or high (5%) entrainment/movement levels but the likelihood of encountering a marked fish would be higher with more marked fish in the population at high entrainment/movement levels (15 vs. 3). Therefore, our data suggests that perhaps one percent of the bull trout above the dam are either entrained or volitionally move below the dam. However, this low rate does not necessarily imply that loss of individuals from the population upstream of the dam is biologically insignificant.

Migratory bull trout appear to have a strong homing tendency and repeatedly return to a previously used spawning tributary (Block 1955; Fraley et al. 1981; Fies and Robert

1988; Goetz 1989; Baxter 1997; Swanberg 1997a; Bahr and Shrimpton 2004; Geist et al. 2004). Molecular genetic (protein and DNA) investigations indicated that genetic variation in bull trout is low in individuals from a population in one tributary but high among populations from different tributaries (Leary et al. 1993; Kanda et al. 1997; Kanda et al. 1997; Taylor et al. 1999; Neraas and Spruell 2001; Costello et al. 2003; Epifanio et al. 2004). This result is what would be expected if bull trout have a high degree of fidelity to their natal tributary. Thus, genetic data supported the hypothesis that bull trout have strong natal homing tendencies. Bull trout also return to previously occupied 'overwinter' or 'maturation' sites soon after spawning (Block 1955; Fraley and Shepard 1989; Elle and Thurow 1994; McLeod and Clayton 1997; Baxter and Nellestijn 2000a; Bahr and Shrimpton 2004; Geist et al. 2004). In their migrations between home spawning tributaries and overwinter sites, bull trout exhibit remarkable fidelity to each locale. (See Appendix 1 for additional discussion about migratory behavior of bull trout.)

The preciseness of their movements makes it especially important that every adfluvial bull trout spawning in a depleted population be given opportunity to home to its spawning tributary because it isn't likely that an individual straying from another tributary will come along to replace it. Thus, loss of a fish from a depleted spawning population will result in a loss of genetic diversity (alleles) in the population and a loss of reproductive potential because the gametes of a large, fecund individual will not be contributed to the population.

Assuming that bull trout in the Pend Oreille Basin between Albeni Falls and Cabinet Gorge Dams home precisely to spawning streams, how much of a threat do losses at Albeni Falls Dam represent? Rieman and Allendorf (2001) determined effective population size (N_e) and genetic conservation criteria for bull trout using the general "50/500 rule". Rieman and Allendorf (2001) used simulation modeling to estimate the number of individuals needed to prevent loss of genetic diversity in a bull trout population. They determined the number of adults needed to ensure no more than a five percent loss in heterozygosity over a period of 200 years. Their modeling was based on effective population size (N_e). N_e measures the rate of genetic drift and loss of genetic diversity associated with inbreeding depression. The N_e = 50/500 rule states that populations with $N_e \leq 50$ are subject to inbreeding depression, which cause allele frequency in the population to immediately become unstable (i.e., lose heterozygosity) and shift away from Hardy-Weinberg equilibrium. In contrast, populations with $N_e \geq 500$ maintain adaptive genetic variation for centuries (i.e., there is little loss of heterozygosity and the allele frequency remains in stable Hardy-Weinberg equilibrium).

The N_e = 50/500 values are useful indicators of the number of individuals in a population (N) needed to protect the genetic variation as described above. For semelparous species that reproduce only once in a lifetime (i.e., they contribute alleles only once) and live in a relatively stable environment, 500 is about the number of individuals (N) that actually need to spawn together to maintain the genetic diversity in the population. However, for iteroparous species (like bull trout) that may spawn on several occasions, the same individual may contribute alleles more than once and mate with individuals from different cohorts (i.e., overlapping generations). Thus, fewer kinds of alleles are transferred in time. If the species is semelparous and 500 fish spawn in each of two generations, 500 independent sets of alleles are transferred in each generation for a total of 1,000 independent sets. If the species is iteroparous and 500 fish spawn in each of two generations, but 50 percent in the second generation had spawned in the first, then 500 independent sets of alleles are transferred in the first generation but only 250 new ones in the second for a total of 750 independent sets. Thus, more than 500 spawning iteroparous fish are needed in each generation to affect the same genetic transfer of 500 semelparous fish.

Rieman and Allendorf's (2001) models simulated these types of age-structured demographic statistics for bull trout and also accounted for environmental stochasticity. Their results indicated that "*genetic variation will be lost through time in isolated populations and this loss will occur more quickly in small populations than in large ones.*" Populations with 500 adults lost about 10 percent of their heterozygosity in 200 years and populations with 250 – 400 individuals lost about 20 – 40 percent of their heterozygosity in 200 years. They determined that for bull trout N_e = 0.5 N, so for N_e = 500, N = 500/0.5 = 1000, and N_e = 50, N = 50/0.5 = 100, i.e., about 100 adults would need to spawn each year to minimize the risk of inbreeding and about 1000 adults would need to spawn each year to maintain genetic variation indefinitely (Rieman and Allendorf 2001). Additionally, bull trout populations with less than 100 spawning adults may be prone to extinction if they are isolated (Rieman and McIntyre 1993; Dunham and Rieman 1999).

The n = 1,000 represents the number of bull trout needed within each tributary to maintain local (adaptive) genetic variation. Recognizing that number might not be achievable Rieman and Allendorf proposed that, "*where local populations are too small, managers should seek to conserve a collection of interconnected populations that is at least large enough in total to meet this minimum. It will also be important to provide for full expression of life history variation and the natural processes of dispersal and gene flow*."

A technical panel convened to integrate conservation genetics into bull trout restoration in the Clark Fork River and Lake Pend Oreille concluded "*Re-establishing connectivity by restoring upstream passage of fish blocked by dams represented the single most important mechanism to reduce the risk of a genetic bottleneck (reduced genetic variation associated with depleted populations)*" (Epifanio et al. 2004). Similarly, the USFWS (2002b) concluded that re-establishing the historic connection with Lake Pend Oreille in Idaho is essential for recovery of the Pend Oreille core area in Washington. Dams on the Pend Oreille River downstream of the lake have negatively impacted the connectivity for fluvial and adfluvial bull trout by isolating bull trout subpopulations, eliminating individuals from subpopulations, and reducing or eliminating genetic exchange. [See also Andonagui 2003.]

A comparison of bull trout redd counts (and spawning escapement; estimated from expanding redd counts) in the main stem and seven tributaries of Lightning Creek (2003 and 2004) was made because one of our radio-tagged fish entered that drainage during the spawning season 2004 (Table 8). Microsatellite DNA studies have shown that each tributary contains its own reproductively isolated spawning population (Spruell et al. 1999; see Appendix 1 for more detailed information about this study). Concern was expressed by Spruell et al. (1999) that extinction was probable if the number of adult spawners continued to remain small. Neither the main stem nor any tributary met the criteria of 1,000 fish needed to protect genetic variability indefinitely in either 2003 or 2004. Only one tributary in 2004 and none in 2003 met the criteria of 100 fish needed to minimize the risk of inbreeding. The minimum spawning escapement estimated was less than 20 fish in six streams in 2003 and less than 30 fish in five of the streams in 2004. An individual bull trout transported above Albeni Falls Dam and migrating into any of these tributaries could potentially have contributed important genetic information to those populations.

Table 8. Redd counts and estimated minimum and maximum spawning escapement in Lightning Creek and its tributaries in 2003 and 2004. Lake total = sum of redds observed in all tributaries of Lake Pend Oreille. Spawning escapement was estimated by multiplying redd counts by 2.2 (minimum escapement) or 3.2 (maximum escapement).

Location	2003			2004		
	Redd counts	Spawning escapement Min est.	Spawning escapement Max est.	Redd counts	Spawning escapement Min est.	Spawning escapement Max est.
Lightning Cr. (main stem)	8	18	26	9	20	29
East Fork Lightning Cr.	38	84	122	77	169	246
Savage Cr.	7	15	22	15	33	48
Char Cr.	7	15	22	14	31	44
Porcupine Cr.	5	11	16	19	22	32
Wellington Cr.	8	18	26	7	15	22
Rattle Cr.	37	81	118	34	75	109
Morris Cr.	1	2	3	1	2	3
Total	111	244	355	166	365	531
Lake Total	812	1,786	2,598	753	1,656	2,406

In 2002, the Kalispel Tribe, in cooperation with the Washington Department of Fish and Wildlife and Idaho Department of Fish and Game, began a genetic inventory of bull trout in the Pend Oreille River between the outlet of Lake Pend Oreille and the confluence with the Columbia River, including the Priest River drainage (Maroney et al. 2003; Olson et al. 2004). Bull trout from this region have not been previously analyzed. Bull trout were collected for this study in 2002 (n = 280) and 2003 (n = 209), with additional collections planned in 2004 and 2005 (Maroney et al. 2003; Olson et al. 2004). In 2002, bull trout were collected from 12 sites in the Priest River drainage (n = 167) and five sites in the Salmo River drainage (n = 177). In 2003, bull trout were collected at seven sites in the Priest River drainage (n=200) and in the Pend Oreille River below Albeni Falls Dam (n = 9). Laboratory analysis is just commencing by the WDFW fish genetics laboratory in Olympia, Washington, who are investigating genetic variation at 13 microsatellite DNA loci (Maroney et al. 2003; Olson et al. 2004). Genetic samples collected from bull trout in the Middle Fork East River (n = 70 in 2003) and from the Pend Oreille River below Albeni Falls Dam (n = 10 in 2003, n = 2 in 2004) by Battelle and EWU crews in 2003 (Geist et al. 2004) and 2004 (present study) were turned over to the Kalispel Tribe for this study.

It was our thought that samples of bull trout collected between Indian Creek and the dam could be compared to samples of bull trout collected from tributaries below and above the dam, similar to a study performed by Neraas and Spruel1 (2001) at Cabinet Gorge Dam. In their study, Neraas and Spruell (2001) compared genetic variation at eight microsatellite DNA loci of bull trout caught immediately below Cabinet Gorge Dam to that of bull trout sampled in tributaries of the Clark Fork River above the dam and in tributaries of Lake Pend Oreille below the dam. They found that the bull trout collected from the tailrace of Cabinet Gorge Dam were genetically more similar to bull trout populations from above the dam than from populations below the dam. Thus, it appeared that Cabinet Gorge blocked migration of adfluvial bull trout back to natal tributaries above the dam.

A similar study at Albeni Falls Dam would require that above dam comparisons be made to bull trout populations in tributaries of Lake Pend Oreille as well as the Priest River drainage. The present radio-tracking study demonstrated that bull trout collected below the dam are as likely to come from populations in Lake Pend Oreille tributaries as populations in the Priest River drainage. The two radio-tagged adults transported above the dam and released near the mouth of the Priest River in 2004 neither entered the Priest River nor dawdled near its confluence. Instead, both fish migrated immediately (within 24 hours of release) upstream to Lake Pend Oreille and one of them was detected in Lightning Creek, a tributary of the Clark Fork River, during the spawning season. Additionally, a bull trout captured in Indian Creek below Albeni Falls Dam was marked with a finclip indicating that it was from either Lightning Creek or Trestle Creek, yet another tributary of Lake Pend Oreille (Lockwood et al. 2001). Also, none of the 131 juvenile bull trout from the Priest River drainage that we injected with PIT tags in 2003 was captured below the Dam in 2004.

When we began to examine the protocol for the current genetic survey (See Maroney et al. 2003; Olson et al. 2004) we noticed that there were no plans to collect any bull trout genetic samples from tributaries of Lake Pend Oreille. This was intentional because other microsatellite DNA studies had already been conducted in the Lake Pend Oreille and Clark Fork above the lake (Neraas and Spruell 2001), including Lightning Creek (Spruell et al. 1999). The participants of the current study figured that they could avoid duplication of effort by comparing their results to studies already accomplished. However, the problem with this idea is that the microsatellite loci mentioned as being examined by Maroney et al. (2003) and Olson et al. (2004) were not the same as those examined by Spruell et al. (1999) and Neraas and Spruell (2001) or other microsatellite DNA investigations of bull trout in the upper Columbia Basin (Taylor et al. 1999, 2001; Costello et al. 2003). [See description of these studies in Appendix 1.]

Table 9 compares the microsatellite loci used in each of these studies with those being screened by Maroney et al. (2003) and Olson et al. (2004). Only a single locus was common to all of the Pend Oreille Basin studies. Therefore, the current survey, as it is presently conceived, will not be comparable to other studies. There are several ways by which this shortcoming could be remedied:

1) The study could be expanded to include genetic samples of bull trout from Lake Pend Oreille tributaries.
2) Assuming that microsatellite DNA in each of these studies was amplified via polymerase chain reaction (PCR) techniques and stored in permanent genomic libraries, it is theoretically possible for each lab that performed these analyses to share their samples. Thus, the WDFW lab could take University of Montana lab samples and test them for alleles screened by the WDFW lab or vice versa.
3) Since the WDFW lab is just commencing their studies they could add the microsatellite loci used by other investigators to their screening protocol.

Specifically this would include: *OCL* 12, *OGO* 2, *ONE* µ7, *OTS* 101, *SCO* 19, *SFO* 18, *SSA* 311, and *SSA* 456.

It would also be useful to collect a larger sample size of bull trout below the Albeni Falls Dam for the genetic analysis. The reason is that microsatellite DNA can assess genetic similarity of populations by two methods: discovery of diagnostic alleles that are unique to one or more populations or through differences in the frequency of alleles that are held in common between populations. Costello et al. (2003) examined microsatellite DNA variation in 37 populations of bull trout from the Columbia, Missouri and Peace River Basins in Alberta and British Columbia and found few diagnostic alleles that differentiated individual bull trout populations. Instead, populations were distinguished by frequency of common alleles. Accuracy of population frequency data is improved by increasing the number of individuals sampled from the population. The present number of bull trout genetic samples from the tailrace area is relatively low (n=12), so better population frequencies could be obtained by increasing the sample size.

Adding bull trout from the Salmo River to the genetic analysis would also improve the study by allowing for a comparison of the relative roles of historical (e.g., post glacial population expansion and colonization, barrier falls) and contemporary (habitat, impassible migration barriers such as dams) factors in structuring the genetic diversity of the Pend Oreille bull trout (see Costello et al. 2003). An effort should be made to obtain the original msDNA data from the studies by Kanda and Allendorf (2001) relating to the Flathead drainage, Neraas and Spruell (2001) relating to the Clark Fork and Lake Pend Oreille tributaries, and Spruell et al. (1999) relating to Lightning Creek to facilitate a basin-wide comparison of genetic population structures.

Table 9. Comparison of microsatellite DNA loci currently being examined in the lower Pend Oreille/Priest River (Olson et al. 2004) with investigations in the Pend Oreille Basin (Spruell et al. 1999; Neraas and Spruell 2001) and throughout their range. A + indicates locus was examined in this study. A * indicates loci shown to be polymorphic for at least some bull trout populations.

***ms*DNA loci**	**Reference**					
	1	**2**	**3**	**4**	**5**	**6**
FGT 3*	+		+			+
OLC 12*	+					
OGO 2*	+		+			
OMM 1070						+
OMM 1128						+
OMM 1130						+
OMY 77*		+		+	+	
ONE µ7*	+		+			
OTS 101*			+			
SCO 19*	+	+	+	+	+	
SCO 23*		+		+	+	
SCO 102						+
SCO 103						+
SCO 104						+
SCO 105						+
SCO 105B						+
SCO 106						+
SCO 107						+
SCO 109						+
SCO 110						+
SFO 18*	+	+	+	+	+	
SSA 197*		+		+	+	
SSA 311*			+		+	
SSA 456*			+		+	
µ*SAT* 73	+					

References (including locations sampled)

[1] Spruell et al. (1999) - Lightning Creek drainage (Lake Pend Oreille tributary)
[2] Taylor et al. (1999) - Peace River Basin, BC; Upper Columbia River Basin (Columbia and Kootenay Rivers, BC); Red Deer River, Alberta
[3] Neraas and Spruell (2001) – Tributary of Clark Fork River above and below Albeni Falls Dam, and Lake Pend Oreille
[4] Taylor et al. 2001 Peace River Basin, BC; Upper Columbia River Basin (Columbia and Kootenay Rivers, BC); Red Deer River, Alberta; Coastal streams.
[5] Costello et al. (2003) - Peace River Basin, BC; Upper Columbia River Basin (Columbia and Kootenay Rivers, BC); Missouri River Basin (Bow and Red Deer Rivers, Alberta)
[6] Olson et al. (2004) - Lower Pend Oreille River, WA; Priest River Basin, ID by allele frequencies.

Recommendations

1. Facilitate migratory fish passage at Albeni Falls Dam. Results obtained during this study were consistent with the hypothesis that Albeni Falls Dam is a barrier to the movement of bull trout in the Pend Oreille River – Lake Pend Oreille watershed. Bull trout originating from tributaries of Lake Pend Oreille and other tributaries upstream of Albeni Falls Dam were captured below the dam. The radio telemetry data suggests that these adult fish were attempting to move back upstream to home spawning tributaries. The number of adult spawners entering most tributaries of Lake Pend Oreille is currently very small and their populations will benefit if small numbers (n = 2 to 10) of individuals are transported above the dam and added back to the tributary population from where they came. Such populations will benefit from adding genes back to the population that would otherwise have been lost. Their population abundance may expand because of increased reproductive potential associated with large, fecund migratory individuals. Bull trout captured below the dam should be released above the dam and allowed to migrate on their own volition to the tributary of their choice. This "lets the fish decide" where it wants to go (see Epifanio et al. 2004 for discussion of this philosophy) and even gives them the option of returning below the dam in the event their home tributary is not located above it.

2. A pilot-scale fish passage evaluation should be employed to determine the most effective means to pass fish over Albeni Falls Dam. If low numbers of adult bull trout return to the base of the dam, it may be more cost effective to construct a trap-and-haul facility to transport fish above the dam individually. If large numbers of adults to return to the base of the dam, it may be more cost effective to construct a fish ladder so individual fish would not have to be handled. We suggest that two types of trap-and-haul options might be employed. One possibility is a trap constructed at the base of the log chute. Advantages of a trap at this location include its apparent attractiveness to salmonids and security. A disadvantage is its proximity to the turbulent waters of the spillway and

powerhouse, which will likely provide competitive attraction flows. A second possibility is construction of a floating trap on a pontoon barge similar to that used by Jensen and Duncan (1971). One advantage of this type of trap is that it could be moved around to different positions in front of the dam to determine which location(s) provide the best attractive flows. Disadvantages are that it would not be as secure as a land based facility on USACE property and potential problem with anchoring in turbulent water. Attractiveness of both traps might be improved by adding small quantities of water from Lake Pend Oreille or Priest River (i.e., potential home tributaries) tributaries to them (see Jensen and Duncan 1971) or placing bull trout in the traps to provide pheromones.

3. Commencing in 2005 attempts should be made annually (in June) to collect bull trout below the dam by electrofishing. This would serve three purposes. First, it would result in the collection of more fish to improve genetic comparisons. (The present sample size, n = 12, is insufficient for making good genetic comparisons; n = 50 should be the goal. We recognize this goal may not be achievable owing to the low capture rates of fish below the dam. However, addition of even 10 more individuals would greatly improve accuracy of genetic information). Second, it would enable testing of the null hypothesis that there is no relationship between discharge and number of bull trout entrained. (The alternate hypothesis that the number of bull trout entrained is positively related to increased discharge would be supported if the null hypothesis was rejected and more bull trout were captured in years with high discharge than in years with low discharge.) Third, it would allow bull trout captured below the dam to be transported above the dam. Concurrent radio tracking and PIT tagging of transported fish would allow for a direct assessment of whether these fish contributed in a genetically meaningful way to their spawning population by comparing the number of transported fish returning to a particular tributary with the estimated spawning escapement (as determined by expansion of redd counts) into that tributary. Future biotelemetry studies should incorporate implanting adult bull trout transported above the dam with combined acoustic and radio transmitters (e.g., CART by Lotek) so their

movements can be followed after they enter the deep waters of Lake Pend Oreille. This would increase the probability that bull trout could be located in the lake and successfully tracked into their spawning tributary. Bull trout should be followed continuously for the first 24 – 48 hours after release as they appear to move very rapidly and directly fro their release site above the dam to Lake Pend Oreille. Electrofishing is a less desirable method for collecting bull trout (because it is more stressful to the fish) than allowing them to migrate into a trap, so as soon as a pilot scale trap facility becomes available it should replace electrofishing as the collection method for performing these studies. Alternative methods could be employed to replace electrofishing for capture of bull trout before pilot-scale fish passage commences. For example, volunteer anglers supervised by biologists from the U.S. Fish and Wildlife Service, Corps of Engineers, Idaho Department of Fish and Game, Washington Department of Fish and Wildlife, and/or Kalispel Tribe could hold annual fish-ins or several in May or June to try to sample bull trout throughout the entire reach from Indian Creek to the base of the dam. However, it should be recognized that catch-and-release angling can be very stressful to fish, especially if they are played for any length of time, so it is uncertain if angling would be less stressful than electrofishing. Additionally, it would be conceivably take more fisheries agency time and money to direct angling activities than conducting electrofishing surveys.

4. Conduct additional studies to characterize the juvenile out-migration of bull trout from the Middle Fork East River. One of the objectives of our original study was to monitor the first out-migration of juvenile fish into the Pend Oreille River. Although our radio-tracking investigations with pre- and post-spawning adults from the Middle Fork East River indicated that they migrated precisely into or out of the Priest River without approaching the forebay of Albeni Falls Dam, we suspected that first time migrants might be more prone to swim downstream than post-spawning adults and, after entering the Albeni Falls forebay, be subjected to entrainment. In trapping and snorkeling surveys conducted during the spring and summer (21 April to 10 July) 2003, we determined that the largest juveniles

present were probably not large enough to be migrants and none of the 15 largest fish tagged with short-lived (two week) radio-transmitters emigrated out of the Middle Fork during this period (Geist et al. 2004). Thus, our objective of assessing the behavior of these fish after their entry into the Pend Oreille River remained unaccomplished. We concluded that it was probable first that juvenile out-migrant bull trout in the Middle Fork have adapted to a fall emigration schedule and proposed to conduct studies during the fall of 2004 to address our original objective. However, insufficient funding in 2004 precluded this work. We still believe that it would be important to accomplish this objective because the Middle Fork East River population resides closer to Albeni Falls Dam than any other, so it seems likely that entrainment would be more likely to occur with individuals from this population than any other. Telemetry (radio or acoustic) using miniature long-lived transmitters would be the most suitable method to accomplish this objective. Radio-transmitters would probably be sufficient to asses the limited objective of determining if juvenile bull trout move downstream after entering the Pend Oreille River and become entrained at, or volitionally pass downstream of, Albeni Falls Dam. However, if juvenile bull trout move upstream after entering the Pend Oreille River and migrate to Lake Pend Oreille, acoustic transmitters may be a better choice, since radio signals would be attenuated and probably undetectable after the fish enters the deep water of the lake.

5. The current genetic inventory being compiled for bull trout in the Pend Oreille Basin downstream from Lake Pend should be reassessed to assure that genetic comparisons can be made with bull trout populations in tributaries of Lake Pend Oreille and the Clark Fork River. Agencies involved with bull trout genetic studies need to collaborate and determine how all samples collected from bull trout in various geographic provinces within the Pend Oreille/Clark Fork Basin can be analyzed by uniform methods to facilitate comparisons. In particular we recommend that the current study being conducted by Maroney et al. (2003) and Olson et al. (2004) either be expanded to include genetic samples of bull trout from Lake Pend Oreille tributaries or the WDFW Genetics Lab screen

microsatellite DNA loci that were used in previously published microsatellite DNA investigations of bull trout in Lake Pend Oreille and Clark Fork River: *OCL* 12, *OGO* 2, *ONE* µ7, *OTS* 101, *SCO* 19, *SFO* 18, *SSA* 311, and *SSA* 456.

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Appendix 1

A literature review on the biology of bull trout *Salvelinus confluentus* (Suckley, 1858), with particular emphasis on the migration of fluvial and adfluvial life history variants, and a description of their distribution in the Pend Oreille/Clark Fork Basin.

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Note: References cited in appendix are included in the Literature cited section of the main report.

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Numerous authors have previously described (reviewed) the taxonomy, distribution, life history, ecology and behavior of bull trout and Dolly Varden (Carl et al. 1967; McPhail and Lindsey 1970; C.J.D. Brown 1971; Scott and Crossman 1973; Russell 1975; Wydoski and Whitney 1979, 2003; Simpson and Wallace 1982; Goetz 1989; Graves et al. 1992; Nelson and Paetz 1992; Pratt 1992; L. Brown 1994; Holton and Johnson 1996; McPhail and Baxter 1996; Behnke 2002; Moyle 2002). Here we update these reports emphasizing the migrations of fluvial and adfluvial bull trout, especially those pertinent to our investigations of bull trout migration in the Pend Oreille River in relation to Albeni Falls Dam. Additionally, we provide a description of the distribution of bull trout in the Pend Oreille/Clark Fork Basin.

Evolution

The bull trout, *Salvelinus confluentus* (Suckley, 1858) is a native char of northwestern North America with distribution centered in the Columbia River Basin. In his systematic review of the genus *Salvelinus*, Behnke (1980) concluded that the probable center of origin of the bull trout was the Columbia River Basin. The oldest *Salvelinus* (initially identified as *Hucho*) fossil in North America was a complete, 668 mm TL, individual recorded from the Miocene Latah Formation at Clarkia Lake (Smith and Miller 1985). Clarkia Lake was formed when a tongue (dike) of basalt lava impounded the St. Maries River, a tributary of the St. Joe River near its confluence with Coeur d'Alene Lake, Spokane River Basin, Idaho 14-16 million years before present (MYBP). Another large *Salvelinus* species, was discovered in Miocene-Pliocene Lake Idaho, Snake River Basin. The fish was present in the Deer Butte (Kimmel 1975) and Glenns Ferry Formations (Smith 1975, Smith et al. 1982), which are remnants of different stages of Lake Idaho respectively 2-3.2 MYBP and 6-9 MYBP. The fish, named *Paleolox larsoni* Kimmel 1975, had jaws 150 mm long and total length of 1200 mm. Smith et al. (1982) noted that certain diagnostic bones of *P. larsoni* were identical to those of modern bull trout but implied no continuity between the two. Later, Stearly and Smith (1993) thought that *P. larsoni* represented either a lineage that gave rise to modern Pacific char or an evolutionary dead end in that line. Upon further reflection, Smith decided it was more appropriate to classify both the *Hucho* from the Clarkia fossil beds and *P. larsoni* from the Lake Idaho fossil beds in the *Salvelinus* clade (G.R. Smith, University of Michigan, Department of Vertebrate Paleontology, Ann Arbor, Michigan, 2004, personal communication to A.T. Scholz, Eastern Washington University, Department of Biology, Cheney, Washington).

Bull trout were thought to have survived the Ice Ages at glacial refugia in the Columbia Basin and have expanded their populations northward during the last 10,000 years (Behnke 1980; Costello et al. 2003).

Taxonomy

The bull trout has received considerable taxonomic scrutiny (Vladykov 1954; McPhail 1961; Morton 1970, 1980; Cavender 1978, 1980, 1984, 1997; Behnke 1980, 1992, 2002; Brown 1984; Haas 1988; Grewe et al. 1990; Haas and McPhail 1991, 2001; Mongillo 1993). Until 1980 it was classified as an interior variety of Dolly Varden, *Salvelinus malma* (Walbaum, 1792). Based on morphological, morphometric, and meristic characters, Cavender (1978) concluded that the two forms should be considered distinct species. Based on Cavender's work, the American Fisheries Society's Committee on Names of Fishes in 1980 officially adopted the scientific name *Salvelinus confluentus* (Suckley, 1858) and common name bull trout for the species (Robins et al. 1980). Additional morphological, morphometric and meristic (Haas 1988; Haas and McPhail 1991, 2001), cytogenetic, i.e., chromosome karyotype (Cavender 1984; Phillips et al. 1989), and molecular genetic (Grewe et al. 1990; Pleyte et al. 1992; Phillips et al. 1994) evidence confirmed this diagnosis. Althought no single character can always distinguish bull trout from Dolly Varden, Haas and McPhail (1991), based on morphometric and meristic analysis of 887 Dolly Varden and 693 bull trout collected throughout their respective ranges, determined that a suite of characters (branchiostegal ray number, anal fin ray count and jaw length) could be combined into a formula that identified them. The best character for separating them was branchiostegal ray count: bull trout have 22-31 (usually 26-31 and mean count of 27) whereas Dolly Varden have 12-25 (usually 17-23 and mean count of 21 or 22) (Cavender 1978; Morton 1980; Haas and McPhail 1991).

Distribution

Dolly Varden are found in coastal streams of the Pacific Northwest from northern California to Alaska and are typically smaller than bull trout. Bull trout occur sympatrically with Dolly Varden in coastal streams and are also found in the interior, east of the Cascade and Coastal Mountains in Idaho, Montana, Oregon, Washington, and British Columbia (Cavender 1978; Behnke 1980; Goetz 1989; Mongillo 1993; Brown 1994; McPhail and Baxter 1996;). Bull trout also occur east of the Continental Divide in Alberta (Nelson and Paetz 1992). Anadromous, adfluvial or fluvial adults usually attain larger sizes than Dolly Varden. Leary and Allendorf (1997) obtained genetic confirmation of sympatric bull trout and Dolly Varden in western Washington. Fixed genetic differences occurred in five of 47 protein-coding loci in bull trout and Dolly Varden populations from streams in Puget Sound and the Olympic Peninsula. No evidence of hybridization or introgression was found, even in streams occupied by both species. More recent genetic evidence (Taylor et al. 1999, 2001) found diagnostic alleles that separated the two species in regions of sympatry; however, evidence of hybridization over much of their range was detected.

Based on their morphometric and meristic identification formula, noted above, Haas and McPhail (1991) classified all (n = 46) of the fish they examined from the Columbia River Basin above Bonneville Dam as bull trout. Taylor et al. (1999, 2001), based on mtDNA analysis, confirmed that bull trout west of the Cascade and Coastal mountains could be distinguished from those of the interior east of these mountains, which suggested that bull trout may have survived glaciation in two refuges; one along the coast, the other in the interior Columbia Basin. No identification of Dolly Varden was made in samples of fish collected from interior drainages.

Genetics

Two types of genetic analyses have been performed with bull trout. In the first category, cytogenetic information (from chromosome karyology studies) and molecular genetic information (from protein and DNA studies) have been employed as tools to investigate the evolutionary phylogenetics of bull trout in relation to other species of the genus *Salvelinus* (Cavender 1984; Phillips et al. 1989, 1992, 1994; Grewe et al. 1990; Phillips and Pleyte 1991; Crane 1991; Pleyte 1991; Pleyte et al. 1992; Crane et al. 1994). In the second category, protein and DNA studies were used to investigate the genetic structuring of extant bull trout stocks at local and regional scales throughout their range (Leary et al. 1991, 1993; Williams et al. 1995, 2001; Kanda et al. 1997; Leary and Allendorf 1997; Spruell and Allendorf 1997; Spruell et al. 1999, 2003; Taylor et al. 1999, 2001; Kanda and Allendorf 2001; Neraas and Spruell 2001; Thomas et al. 2001; Costello et al. 2003; Olson et al. 2004;).

Proteins describe an organism's phenotype and DNA describes its genotype. Both protein and DNA methods provide descriptions about the different alleles representing a particular gene locus that is present in a population. DNA methods are generally preferred over protein methods because they offer a better chance of detecting allelic variation, i.e., the amino acid sequence of a protein may be represented by more than one nucleotide base sequence in DNA owing to the redundancy of the genetic code. Silent mutations in the genome would, thus, be undetected in the proteins whereas they could be detected by examination of the DNA. Moreover, proteins are more difficult to isolate and they must be taken from tissues in which they are present in great abundance such as liver or plugs of muscle. This type of sampling can be lethal to the fish.

In contrast, DNA can be collected by taking a biopsy sample (e.g., using a hole punch to remove a piece of tissue from a fin) and storing it in 100 percent ethanol. DNA extraction is easy compared to the relatively more complicated processes involved in protein extraction. Extracted DNA can be amplified using polymerase chain reaction (PCR) techniques and stored in a genomic library (cloned bacteria or phages), so there is a permanent record of the individual's entire genome (or at least the portions of it that were amplified) on file that can be used for future genetic studies.

Allozymes (a synonym of isozymes) are variants of enzymes (especially metabolic enzymes used for respiration) or structural proteins that have slightly different amino acid sequences. The variations are produced by slight variations in the nucleotide sequence of DNA, hence they represent allelic variants of the same gene. An allozyme variant of one enzyme may have different temperature or pH optima than other allozyme versions of that enzyme. This is especially important to fishes and other poikilotherms because it allows them to be active over a range of temperatures. Although metabolic enzymes tend to be conserved and change relatively slowly over evolutionary time, the types of variants present in a population may reflect adaptation (via natural selection) to local environmental conditions. [e.g., Individuals with alleles that coded for enzymes with higher temperatures over time may have survived in warm water and reproduced whereas those lacking those alleles perished.] Salmonid fishes were thought to have arisen in a tetraploid event and are gradually being restored to a diploid condition. One result was addition of a second set of alleles representing each gene that increased the number of alleles (hence, variation) present in an individual. Allozyme alleles are detected by extracting the enzyme from certain types of tissue and subjecting it to gel electrophoresis. The allelic variants separate by traveling different distances along the gel plate based on their size and charge. The gel plate is treated with specific stains that activate the enzymes allowing their visualization. Homozygous dominant, homozygous recessive and heterozygous individuals can be distinguished by the kinds of bands present (one for homozygotes, two for heterozygotes) and the distance traveled along the gel plate (dominant vs. recessive alleles).

Mitochondrial DNA (mtDNA) is useful for molecular genetics investigations because it is composed of 37 genes that evolve faster than most nuclear genes. These genes code for proteins used as enzymes in Kreb's cycle and electron transport system. The more slowly evolving regions are useful for phylogenetic studies, while the more rapidly evolving regions are useful for investigating population genetic structure. Since mtDNA is maternally inherited, each gene is represented by a single allele, making interpretations about the divergence of the nucleotide sequence between populations or species easier to analyze. Differences in mtDNA are detected by treating it with several restriction enzymes (endonucleases) that break it into restriction fragments of different sizes. Restriction fragments are identified by size (using gel electrophoresis) and are separated by the speed with which they migrate through a gel plate. Since the nucleotide bases in the fragment contain negatively charged phosphate groups, the fragments are attracted to the positive end of the gel plate. Small fragments move more quickly through the gel than large fragments. The suite of fragments produced in this manner is termed a haplotype. Different haplotypes are recognized by restriction fragment length polymorphisms (RFLPs). The number of different haplotypes (and frequency of each type of haplotype) is a reflection of the DNA variation within and/or between populations.

Microsatellites are a category of highly repetitive DNA (satellite DNA) that consist of short tandem repeats 2-4 base pairs long and repeated for n times, e.g., $(AT)_n$, $(ATT)_n$, $(ATTC)_n$, that provide both maternal and paternal information. Microsatellites undergo fast rates of evolution, so they are particularly useful indicators for ascertaining population genetic structure. Genetic variation is determined by the number of times (n) the sequence is repeated. The DNA is amplified via the Polymerase Chain Reaction (PCR) and automated DNA sequencers detect the fragment length. Homozygotes are identified by fragments of one length whereas heterozygotes are detected by fragments of two lengths.

Evolutionary Phylogenetics

Salvelinus systematics and evolution was examined by using morphological, morphometric and meristic characters (Behnke 1980; Cavender 1980; Stearly and Smith 1993), chromosome karyotyping (Cavender 1984; Phillips et al. 1989), allozymes (Crane 1991; Crane et al. 1994), mitochondrial (mt) DNA (Grewe et al. 1990), or nuclear DNA that codes for ribosomal RNA genes (rDNA) (Pleyte 1991; Phillips and Pleyte 1991; Phillips et al. 1992, 1994) data to conduct cladistic analyses both within the genus and with other genera of salmonids. Collectively, these studies indicated:

1) *Salvelinus* is composed of three distinctive subgenera: *Salvelinus* (*Salvelinus*) containing the arctic char (*S. alpinus*) and Dolly Varden (*S. malma*), *Salvelinus* (*Baione*) containing the brook trout (*S. fontinalis*), and *Salvelinus* (*Cristivomer*) containing the lake trout (*S. namaycush*). The Dolly Varden and arctic char were sister species that shared a common ancestor. The allozyme and rDNA data indicated that brook trout and lake trout were also sister species that shared a

common ancestor, but have diverged to respectively to occupy fluvial and lacustrine niches.

2) Placement of the bull trout (*S. confluentus*) within these subgenera was unresolved. Although most commonly associated with Dolly Varden, its proteins and DNA were more similar to that of the iwana (*S. leucomaensis*), a char indigenous to Asia, than to members of the subgenus *Salvelinus* (*Salvelinus*). Therefore, allozyme and DNA data confirmed the conclusions based on morphology, morphometry and meristics (Cavender 1978; Haas 1988; Haas and McPhail 1991) of a dichotomy between bull trout and Dolly Varden;

3) There are conflicting results about which of these lineages was most divergent from the primitive salmonid genus *Hucho*, which includes the Siberian huchen (also called taimen), *Hucho perryi*. Morphological data (Stearly and Smith 1993) suggested that *Salvelinus* (*Cristivomer*) most recently evolved (i.e., shared the greatest number of characters with *Hucho* among all *Salvelinus* species). Cytotaxonomy data based on karyotyping (Cavender et al. 1984; Phillips et al. 1989), allozyme data (Crane 1991; Crane et al. 1994), mtDNA data (Grewe et al. 1990) and rDNA (Phillips et al. 1994) all suggested that *Salvelinus* (*Baione*) was the most divergent and *Salvelinus* (*Salvelinus*) most recently evolved, with *S. confluentus* a recent offshoot of the *Salvelinus* (*Salvelinus*) complex. Genomic DNA (rDNA) data (Phillips and Pleyte 1991; Pleyte 1991; Phillips et al. 1992, 1994; Pleyte et al. 1994) indicated that *S. confluentus* and *S. leucomaensis* were most divergent, and that the *Salvelinus* (*Salvelinus*) complex and a second complex that included *Salvelinus* (*Baione*) and *Salvelinus* (*Cristivomer*) were more recently evolved, diverging at about the same time.

4) The genera of Salmoninae originated in the late Miocene to early Pliocene and extant species originated during the late Pliocene to early Pleistocene (Grewe et al. 1990). Estimates were based on using genetic divergence data from mtDNA to construct a distance phenogram representing the phylogeny of the Salmoninae. These results were consistent with the fossil record, which indicated that the oldest salmonid so far described was a grayling-like ancestor, *Eosalmo driftwoodensis*, found in Eocene (50 MYBP) deposits in British Columbia and

near Republic, Washington (Wilson 1977, 1978). A gap of about 30-35 million years then occurs in the fossil record until several distinctive salmonid species allied to modern genera were described from rock formations that are of Miocene-Pliocene age, such as Lake Idaho's *Paleoesox larsoni* which shared features with both *Hucho* and *Salvelinus* (Smith et al. 1982) and Clarkia Lake's *Hucho* sp. (Smith and Miller 1985), both now considered *Salvelinus* as noted above.

Population Genetic Structuring

Population genetic structure of extant bull trout stocks has been examined using proteins (isozymes) (Leary et al. 1991, 1993; Kanda et al. 1997; Leary and Allendorf 1997), mitochondrial DNA (mtDNA) (Leary et al. 1993; Williams et al. 1995, 1997; Taylor et al. 1999, 2001; Kanda and Allendorf 2001; Latham and Taylor 2001), microsatellite DNA (msDNA) (Spruell and Allendorf 1997; Spruell et al. 1999, 2003; Kanda and Allendorf 2001; Latham and Taylor 2001; Neraas and Spruell 2001; Taylor et al. 2001; Costello et al. 2003; Olson et al. 2004), and randomly amplified polymorphic DNA (RAPD) (Thomas et al. 2001). Collectively, these investigations have revealed that there is little genetic variation within local bull trout populations, but substantial genetic differences among them. The large amount of genetic divergence among populations indicated that local populations represent distinctive, reproductively isolated stocks.

These points hold true for both broad and narrow geographic scales. For example, on a broad scale, Leary et al. (1993) examined electrophoretic mobility of isozyme coding loci in 20 bull trout populations spread across the Columbia Basin in British Columbia, Idaho, Montana, Oregon and Washington. They detected genetic variation at 10 of 51 loci examined. Genetic variation in each isolated population was low but genetic divergence between populations was high, leading them to conclude that, "*Preserving the genetic diversity of bull trout will require the continued existence of many populations throughout this region*."

On a narrower geographic scale Kanda et al. (1997) examined 45 isozyme coding loci in 24 bull trout populations from the Flathead River Basin, Montana. Populations were sampled from different tributaries in five major drainages: North Fork Flathead River (n=6 tributary populations), Middle Fork (n=5), South Fork (n=7), Swan River (n=4) and Stillwater (n=2). Individuals representing two or more cohorts were collected from each population when possible to assess temporal patterns of genetic variation as well as spatial differences. The point of examining temporal variation was to determine if local populations were in Hardy-Weinberg equilibrium, since maintenance of Hardy-Weinberg equilibrium over time characterizes reproductively isolated stocks. Little genetic variation was detected within individual populations or year classes within a population, but statistically different allele frequencies (at five loci) were evident in each of the five major drainages (Kanda et al. 1997). Genetic diversity was apportioned in a hierarchal order: 1.4 percent to year classes within a population, 7.3 percent to tributary populations within a drainage, 28.5 percent among different drainages and 62.8 percent to individual populations (Kanda et al. 1997). These data suggest there was relatively little straying of fish between the five drainages during spawning migrations (even though adfluvial fish from the Middle Fork and North Fork of the Flathead Rivers and Stillwater drainage all intermingled in Flathead Lake) because allele frequency of fish in each drainage appeared to be well differentiated and these differences were maintained over time. Within a drainage it appeared that more “wandering” occurred between tributaries during spawning migrations, i.e., reproductive isolation was not so complete because allele frequencies were more similar to other tributaries within a drainage than to tributaries in other drainages. This suggested that each of the five drainages may contain a metapopulation rather than isolated parent stream populations.

Kanda and Allendorf (2001) later examined the genetic population structure of these same Flathead Basin populations using mtDNA and msDNA. They found no evidence of metapopulation structuring. Instead, each tributary had its own distinctive population.

At an even smaller scale, Spruell et al. (1999) used msDNA (six loci) to determine the genetic population structure of bull trout from five tributaries of Lightning Creek, a tributary of Lake Pend Oreille. Their data showed each population within Lightning Creek had its own distinctive allele frequency which was temporally stable among different cohorts. Spruell et al. (1999) concluded, it was therefore unlikely that extensive dispersal has linked tributaries in a manner consistent with a metapopulation structure:

“*The genetic results indicated that Lightning Creek bull trout have not historically existed as a metapopulation with frequent extinction and recolonization or demographic support among tributary populations*,” instead the temporal stability of allele frequencies in each population supported “*the conclusion that these populations were formerly large and discrete*.” However, demographic data collected by IDFG indicated a variable but downward trend in redd counts in Lightning Creek tributaries. The low number of spawning individuals combined with the degree of [reproductive] isolation indicated by the genetic data suggested that extinction of the tributary populations is probable if population sizes continue to remain small (Spruell et al. 1999). Recovery was possible if the downward trend can be reversed as there was still a considerable amount of genetic variation remaining in these populations (Spruell et al. 1999).

Taylor et al. (1999) and Costello et al. (2003) examined geographic variation at seven msDNA loci in 37 populations of bull trout in Alberta and British Columbia, including 12 populations from tributaries of the Pine River drainage (Peace River Basin), 15 populations from tributaries of the Kootenay and upper Columbia Rivers (Columbia River Basin) and 12 populations from tributaries of the Bow and Red Deer drainages (Missouri River Basin). Low intrapopulation microsatellite variation was found but high interpopulation divergence was observed (Costello et al. 2003).

Thomas et al. (2001) examined genetic variation in 23 local populations of bull trout from six river drainages (Athabasca, Bow, North Saskatchewan, Oldman, Peace and St. Marys) in Alberta and Montana using random amplified polymorphic DNA (RAPD). Each drainage had its own genetically distinctive bull trout population. Local populations in tributaries within each drainage were also genetically distinctive from one another. Genetic distance was nested, with greater genetic distance between drainages than tributaries within a drainage. These data were consistent with the hypotheses that: 1) bull trout exhibit precise homing to natal streams because each tributary had its own distinctive population genetic signature; and 2) bull trout form metapopulations within a drainage (which was possibly related to occasional “wandering” or “straying” of individual fish between populations) because various tributary populations within a drainage had lower genetic distance when compared to tributaries from a different drainage (Thomas et al. 2001).

Latham and Taylor (2001) examined mitochondrial DNA restriction fragments and four microsatellite DNA loci in 14 populations of bull trout collected in tributaries of the Columbia River above Hugh Keenlyside (n = 9), Revelstoke (n = 3) and Mica (n = 1) dams. Each tributary had a distinctive population based upon allele frequencies of mtDNA haplotype and msDNA loci. There were also differences within isolated segments. For example, bull trout populations above Revelstoke and Mica Dams had a higher frequency of one mtDNA haplotype and one msDNA allele than populations in Keenlyside Reservoir, which had higher frequency of the opposite haplotype and allele.

Genetic investigations can reveal genetic differences between populations through discovery of diagnostic alleles that are unique to one population or through differences in the frequencies of common alleles. Costello et al. (2003) noted that, "*there were few instances of alleles being unique to particular bull trout populations*." Instead, populations were differentiated by having a distinctive frequency of alleles common to all bull trout populations in an area.

It is thought that the low levels of population variability observed in bull trout are related to their postglacial dispersal from refugia in the interior Columbia Basin (McPhail and Lindsey 1986). They are thought to have gradually expanded their range northward over a distance of about 2000 km over the past 10,000 years as the Cordilleran ice lobe retreated. Thus, their low levels of intrapopulation genetic variability were attributed to genetic bottlenecks associated with small founding populations during colonization events (Costello et al. 2003; Taylor et al. 1999). In support of this theory, Costello et al. (2003) found that bull trout populations on the periphery of their range had lower numbers of alleles and heterozygosities than bull trout populations closer to the center of the putative glacial refugia. After post glacial dispersal, the next most important factor influencing genetic variation on both regional and local geographic scales were migration barriers, both natural and man made (Costello et al. 2003).

Neraas and Spruell (2001) provided an example of how hydroelectric dams contributed to the loss of genetic variation. Bull trout populations in tributaries of the Clark Fork River upstream of Cabinet Gorge Dam have declined since the dam was constructed in 1952 without a fish ladder. Each year adult bull trout, believed to be adfluvial migrants from upstream tributaries, collect below the dam. Neraas and Spruell (2001) compared msDNA (eight loci) of bull trout captured below the dam to that of bull trout captured in tributaries of the Clark Fork (above the dam) and tributaries of Lake Pend Oreille (below the dam). They found that the Cabinet Gorge bull trout were "*most likely individuals that hatched in tributaries above the dam, reared in Lake Pend Oreille, and could not return to their natal tributaries to spawn*." Thus, since bull trout blocked by the dam are not contributing to the gene pool of their natal tributary, continuing lack of passage is causing continuing loss of genetic diversity in tributaries above the dam.

Williams et al. (1997) examined mtDNA variation in 17 populations of bull trout from Idaho (n=7), Oregon (n=8) and Washington (n=2) in the Columbia and Klamath River Basins. Their results suggested that genetic variation in bull trout is geographically structured into four distinctive units: 1) Klamath; 2) Lower Columbia (downstream of John Day Dam); 3) Middle Columbia (including tributaries of the Columbia and between John Day and Grand Coulee Dams and tributaries of the Snake River); and 4) upper Columbia (above Grand Coulee Dam, including the Pend Oreille/Clark Fork and Spokane/Coeur d'Alene rivers).

In the Klamath and lower Columbia individuals within local populations exhibited low within mtDNA variation. The Klamath populations and lower Columbia River populations were separated from the Middle Columbia populations, and from each other, by the presence of single diagnostic haplotypes in each tributary population. Most populations (seven of 13) in the mid Columbia (and Snake) tributaries shared a common haplotype that was the only or most common haplotype in those populations. The remainder of the mid-Columbia (and Snake) populations were characterized by a low number (usually 1-2) of other haplotypes.

In contrast, the three upper Columbia populations, one from the Clark Fork River, another from a tributary of Lake Pend Oreille (Gold Creek), and a third from a tributary of the St. Joe River (Medicine Creek), contained a low frequency of the common mid-Columbia haplotype and were represented by a large number (usually 3-5) of haplotypes that were unique to each tributary. These findings suggested that bull trout populations in the Pend Oreille/Clark Fork Basin contain "*a substantial [amount] of the remaining natural genetic diversity in the bull trout species*" (Williams et al. 1997). These results are also consistent with the speculation that the Pend Oreille/Clark Fork Basin may represent the remnant of the glacial refuge population of bull trout. Assuming these inferences are correct, they elevate the importance of protecting bull trout in the Pend Oreille/Clark Fork Basin.

Temperature Preference

Bull trout prefer cold water and are uncommon where water temperatures rise above 15 °C for extended periods (Goetz 1989; McPhail and Baxter 1996). In the Cascade Mountains of Washington and Oregon juvenile bull trout were not found in streams where maximum water temperature exceeded 14 °C (Goetz 1997). Similarly, in tributaries of Lake Pend Oreille, Idaho, juvenile bull trout occurred in relatively high densities (4-11 fish/100 m^2) in tributaries with summer temperatures ranging from 7.8-13.9 °C but in relatively low densities (0-<1/100 m^2) in tributaries with summer temperatures ranging from 18.3-23.3 °C (Saffel and Scarnecchia 1995). Adult bull trout prefer water temperatures below 15 °C and are rarely found where temperatures exceed 16.5 °C. Their upper tolerance appears to be about 18.5 °C.

Life History Variations

Bull trout have a variety of life history forms within the same watershed. In interior watersheds, these variants include resident, and migratory forms.

Resident Life History

Resident forms usually occur in headwater tributaries above natural barriers that are insurmountable by migratory bull trout (Goetz 1989; McPhail and Baxter 1996). Resident bull trout adults attain maximum lengths of 200-300 mm and become sexually mature at age 3-4, one or two years earlier than migratory forms. Although resident forms are usually rather sedentary (there must be strong selection against downstream migration in these populations otherwise they would not persist above barrier falls), radiotracking investigations of resident bull trout residing in headwater tributaries (Meadow and Daly Creeks) of the Bitterroot River, Montana, revealed that they make local seasonal movements for spawning and for avoiding ice (Jakober 1995; Jakober et al. 1998; see also general discussion by Gowan et al. 1994). Upstream movements in September for spawning ranged from 0.1-0.3 km. Downstream movements associated with post-spawning and avoidance of ice ranged from 0.1-12.9 km (Jakober et al. 1998).

Resident bull trout tagged with conventional tags and radio transmitters in the Tucannon River, Washington migrated upstream 25-75 km in June and July to spawning sites near the headwaters. After spawning in early September, they made post-spawning movements in late September and October to overwinter in the lower river (Faler et al. 2003, 2004; Martin 1992; Martin et al. 1992; Underwood 1996; Underwood et al. 1994). None of 16 fish radio-tagged in 1992 or 76 fish radio-tagged in 2002/2003 were detected at a location other than Tucannon River, although contact with two of the fish in 1992 was lost after they had returned to the lower river and it was suspected that they had moved into the Snake River (where deep water attenuated the radio signals). Hence, a portion of the fish in the fish in the Tucannon may have a migratory life history.

Migratory (Fluvial/Adfluvial) Life History

Migratory forms include fluvial and adfluvial life histories. Fluvial bull trout usually reside it their home tributary for one to four years before migrating into a larger river whereas adfluvial bull trout reside in their home tributary for one to four years before migrating to a lake. Emigration typically occurs in spring and summer. After maturing in the lake or river in about one to three years, they return to spawn in their natal tributary.

Migratory bull trout appear to have a strong homing tendency, returning to their home streams from spring to early autumn and spawning from early September to mid October. They return to previously occupied overwinter sites soon after spawning. In their migrations between home spawning tributaries and overwinter sites, they exhibit remarkable fidelity to each locale. (Described below in detail.)

Juvenile Outmigrations

Migratory bull trout juveniles usually leave their home tributary at age 2-3, when they attain total lengths of 170-300 mm. Evidence includes:

- Bjorn (1961) determined that bull trout in Priest Lake, Idaho spent 2-3 years in tributaries before immigrating to the lake. His conclusions were based on analysis of their scales which showed the first two or three annuli close together (indicating stream residence) and the next annulus separated by a wide distance (indicating a transition to lake residence).
- Most bull trout in tributaries of Lake Pend Oreille, Idaho (e.g. Gold, Grouse, North Fork Grouse and Trestle Creeks, and Pack River) were adfluvial and emigrated from their home tributary to the lake at age 1-3 (Hoelscher and Bjornn 1989; Pratt 1985; Pratt and Huston 1993; Saffel and Scarnecchia 1995). Migration peaked in May.
- In a study of Flathead River, Montana bull trout, Fraley and Shepard (1989) determined that most juveniles emigrated from tributaries of the upper Flathead River to Flathead Lake at ages 2 (49%) and 3 (32%), with lower numbers at ages 1 (18%) and 4 (1%). Emigration occurred primarily in July through August. Juveniles moved out of tributaries into the main stem of the Flathead River in June and July. Migrations from the main stem to Flathead Lake took place in August and September; so juvenile emigrants where highly mobile throughout the summer.
- In the Metolius River, Oregon juvenile adfluvial bull trout emigrated from tributary streams into the main river channel and into a main stem reservoir (Lake Billy Chinook) predominately at age 2 (Ratliff et al. 1996). Their migration took place in May and June at night.
- In Mill Creek (Walla Walla Sub-basin), Washington, fluvial (and probably some resident) juveniles, predominately 170-230 mm TL, were caught in a

downstream migration trap set in the Mill Creek main stem from early April through September (Hemmingson et al. 2000, 2001, 2002). Catch peaked in April, remained high through June and gradually tapered off after the first week in July. Radio telemetry investigations demonstrated that this population remains continuously within the Mill Creek drainage. None were detected entering the Walla Walla River which was impaired by high summer temperatures (above bull trout thermal tolerance). The Mill Creek bull trout spawned in Mill Creek and its tributaries.

- Most fluvial bull trout outmigrating from the Rapid River into the Salmon River, Idaho were age 2-3 and 180-300 mm TL (Elle and Thurow 1994).

Adult Spawning Migrations

Age at Sexual Maturity

Fluvial and adfluvial bull trout usually become sexually mature at age 5-6 (2-4 years after reaching the lake or river), at 400-600 mm TL, and typically live until age 9-11 (occasionally up to 20-24 years in slower growing populations) (Bjorn 1961; Fraley and Shepard 1989; McPhail and Baxter 1996). Fraley and Shepard (1989) reported that the youngest bull trout recorded spawning in the Flathead and Swan Rivers, Montana was age 5 and the majority was age 6-7. In tributaries of Lake Pend Oreille, most first time spawners were six years old (Pratt 1985). Older adults of fluvial populations attain maximum lengths of about 400-600 mm whereas those of adfluvial populations attain maximum total lengths of about 500-1,000 mm (Brown 1994; Goetz 1989; McPhail and Baxter 1996). Both types of migratory bull trout are iteroparous and may spawn annually or every other year, depending on the productivity of their environment for gameteogenesis (Goetz 1989; McPhail and Baxter 1996).

Spawning Season

Bull trout typically spawn in September or early October.

- Bull trout spawning occurred from September to early October in the Athabasca River, Alberta (McLeod and Clayton 1997); Oldman River, Alberta (Fernet and O'Neil 1997); Morice River, British Columbia (Bahr and

Shrimpton 2004); Middle Fork East River, Idaho (Dupont and Horner 2004); lower Clark Fork River, Idaho (Heimer 1965); Flathead River, Montana (Block 1955; Fraley and Shepard 1989); Blackfoot and upper Clark Fork rivers, Montana (Swanberg 1997a ,1997b); Metolius River, Oregon (Thiesfield et al. 1996); Wenaha River (Grande Ronde sub-basin), Oregon (Hemmingson et al. 2000, 2001, 2002); Mill Creek (Walla Walla sub basin), Washington (Hemmingson et al. 2000, 2001, 2002); Tucannon River, Washington (Martin 1992; Martin et al. 1992; Underwood 1996; Underwood et al. 1994);.

- The spawning migration of adfluvial bull trout in Meadow Creek, a tributary that enters the Duncan River about 4.8 km above its junction with Kootenay Lake, British Columbia, lasted from July 23 to September 26 and peaked in August (Leggett 1969).
- In the Salmo River, tributary of the Pend Oreille River, British Columbia, spawning peaked during the first two weeks of September (Baxter and Nellistijn 2000a or b).
- McPhail and Baxter (1996) reviewed 13 papers that dealt with spawning of bull trout spanning 16° of latitude (44-60°N). Spawning time ranged from mid August to late October depending upon when the threshold temperature dropped below 9°C. Most populations spawned between September 1 and October 10.

Pre spawning Movements

Sexually mature migratory bull trout commonly begin spawning migrations in May or June during the spring freshet and enter spawning tributaries about two months prior to spawning in September. This behavior is especially prevalent in bull trout populations occupying the Pend Oreille/Clark Fork Basin, Idaho and Montana. This early migration is a critical life history adaptation that allows fish to access spawning tributaries that have intermittent reaches during the summer and fall months (Pratt 1985; Pratt and Huston 1993; PBTTAT 1998). The geology of this basin is such that many streams have influent reaches, especially near mouths, that are above the level of the water table. Water is maintained in the channel during peak flows but sinks into the ground during low flows. Routine occurrence of subsurfacing during average and below average runoff years would likely provide a strong natural selection force favoring of individuals with an early migration schedule, which could be considered a local adaptation to the environment. Examples where bull trout prespawning movements occurred in late spring or early summer, included:

- Some bull trout migrated from Lake Pend Oreille into larger tributaries in May to July (Anderson 1971; Jeppson 1960; Mallet 1968; Pratt 1984, 1985; Pratt and Huston 1993). For example, numerous large, sexually mature bull trout (1.8-6.8 kg) were observed in the main stem and tributaries of Lightning Creek, in June and July (Anderson 1971). Lightning Creek drains into the lower reach of the Clark Fork River inundated by Lake Pend Oreille.
- Tagging and radio tracking investigations with adfluvial bull trout in Flathead River (Fraley and Shepard 1989), fluvial bull trout in the Clark Fork/Blackfoot rivers (Swanberg 1997a, 1997b) and resident bull trout in the Bitterroot River system (Jakober 1995; Jakober et al. 1998) have also revealed that bull trout commence spawning migrations in June.
- Spawning and non-spawning bull trout in the Blackfoot River, near Missoula, Montana, migrated upstream and entered tributaries (North Fork and Monture Creeks) in June and July (Swanberg 1997a). Spawning fish ($n = 7$) ascended the spawning tributaries in late June or July and remained in them for 67 ± 10 days before spawning and returning downstream in September (Swanberg 1997a). Non-spawning fish ($n = 14$) entered the tributaries after the spawners in July. They remained in them for 28 ± 18 days before returning down river in late August. Upstream migrations in June and July were nocturnal and rapid (4.4 ± 2.2 km/day). Swanberg speculated that early migration "*may have evolved as a strategy to avoid seasonally unfavorable conditions in the Blackfoot River where ambient temperatures can exceed 20 °C.*" Swanberg noted that movement into the tributaries where water temperatures were <15 °C would reduce metabolic costs by at least 12-20 percent and conserve

energy for reproduction. Similarly, bull trout in the warm upper Clark Fork River moved into a relatively cooler tributary (Rock Creek) in July (Swanberg 1997b).

- Non-spawning bull trout (and Dolly Varden) may migrate along with sexually mature adults into spawning tributaries in May and June (Armstrong and Morrow 1980; Brown 1994). Their migration appeared to be related to avoidance of high temperature in the main river.
- Entry of sexually mature fluvial bull trout into tributaries of the Morice River, Skeena River Basin, northwestern British Columbia, occurred up to three months in advance of their September spawning period (Bahr and Shrimpton 2004). Temperature was apparently not the motivation for their early migration because the temperature of the Morice River main stem remained continuously ≤ 14 °C.
- Radio telemetry investigations revealed that adfluvial bull trout captured at the head of Lake Billy Chinook migrated upstream into the Metolius River and its tributary streams between May and August: one in May, one in June, seven in July and three in August (Thiesfeld et al. 1996).
- Radio tracking studies indicated that nine fluvial bull trout in the Athabasca River, Alberta had all initiated upstream movements by mid July and entered spawning tributaries in August (McLeod and Clayton 1997).
- Upstream migration of fluvial bull trout from the Salmon River into the Rapid River, Idaho occurred during the falling hydrograph following peak runoff in May to July (Elle and Thurow 1994).
- Upstream migration of mature resident bull trout from the lower Tucannon to upper Tucannon spawning sites commenced in late June and July. The fish spawned from late August to mid September (Faler et al. 2003, 2004; Martin 1992; Martin et al. 1992; Underwood 1996; Underwood et al. 1994).
- Radio-tagged bull trout (n = 15), 365-543 mm FL, moved up the Umatilla River, Oregon into its North Fork in May to August; after spawning they

moved back downstream to overwinter areas in the Umatilla main stem in late September and mid-October (Sankovich et al. 2003, 2004).

- In the Salmo River, radio-tagged bull trout (n = 9) migrated either upstream or downstream from holding areas to spawning sites in the main stem or tributaries between 15 July and 10 August (Baxter and Nellistijn 2000a).

A late summer/early fall spawning migration also occurs from Lake Pend Oreille into the Clark Fork River and tributaries entering along the Clark Fork (Jeppson 1960; Pratt 1985; Pratt and Huston 1993; PBTTAT 1998). A portion of the spawning population in Lightning Creek enters in August or September. Late summer or fall migration is potentially advantageous in terms of reproductive fitness because the fish remains in a more productive environment continuing to feed for a longer period, and converting more energy into gamete production. Hence, fecundity of late migrating spawners may be greater than that of early migrating spawners which enter less productive tributary environments. The contrasting strategies of early or late migration could thus both be the result of natural selection, similar to balanced polymorphism. The downside of later spawning migration is that intermittent stream reaches may block migration into home rivers or natal tributaries and increase the probability of straying.

Distance Traveled During Migration

Conventional tagging and radio telemetry investigations have demonstrated that fluvial and adfluvial bull trout frequently make migrations between spawning and wintering areas of 50-200 km (Block 1955; Bjornn and Mallet 1964; Thiesfeld et al. 1996; Swanberg 1997a; Hemmingson et al. 2000, 2001, 2002; Faler et al. 2003, 2004; Bahr and Shrimpton 2004). Adfluvial bull trout routinely traveled 88-250 km from Flathead Lake to reach spawning tributaries in the North and Middle Forks of the Flathead River (Fraley and Shepard 1989). Jaw tagged bull trout moved up to 325 km from their original tagging sites in the Middle Fork Salmon River, Idaho (Bjornn and Mallet 1964) and a radio-tagged bull trout traveled over 357 km from Kootenay Lake into a headwater breeding stream of the Duncan River, British Columbia (O’Brien 1997).

Repeat Homing to Previously Used Spawning Sites

Bull trout tend to exhibit strong fidelity to sites previously used for spawning and repeatedly return there over several years in succession. This behavior had been documented by Block 1955, Fraley et al. 1981, Fies and Robert 1988, Goetz 1989, Baxter 1997, Swanberg 1997a, Bahr and Shrimpton 2004 and Geist et al. 2004. Marked adfluvial bull trout in the Flathead River, Montana returned with great precision to the tributary where they had been marked in a previous spawning season (Block 1955; Fraley et al. 1981). Several of them returned to the same specific spawning area within their tributary (Fraley et al. 1981). One fluvial bull trout tracked in the Blackfoot River, Montana, returned to spawn in the same general vicinity of the same tributary for two years in succession (Swanberg 1997a). One tagged female returned to the same nest site in a tributary of the Metolius River, Oregon for three years in succession (Fies and Robert 1988; Goetz 1989).

Seventy fluvial bull trout in the Morice River, British Columbia were implanted with radiotransmitters (Bahr and Shrimpton 2004). Individual fish were tracked over two spawning seasons to evaluate repeat homing. Mature fish migrated from the main stem into five different spawning tributaries from June to September and returned to the main stem soon after spawning in September. Fish that spawned in both years of the study returned to the same tributary in the second year. In fact, they utilized the same location within each of the five tributaries that they used during the first year.

However, there is contradictory evidence for homing in bull trout. There is a suggestion that bull trout in a tributary (McKenzie Creek) of the Arrow Lakes, Columbia River, used a different tributary in successive spawning seasons (McPhail and Murray 1979). [Their evidence stemmed from the observation that only two of 65 post-spawning outmigrants tagged in 1977 returned to McKenzie Creek during the 1978 spawning season. These data coupled with the observation that few large-sized bull trout spawned in McKenzie Creek, but larger tributaries nearby had many large sized adults, lead McPhail and Murray to speculated that bull trout have "*an apparent tendency to switch to new and larger spawning streams as individuals grow*." It should be noted that their evidence for this conjecture was strictly circumstantial. They had no direct evidence, such as fish tagged in one tributary but recaptured in a larger one later, to back up their argument.] Bull trout in tributaries of Lake Pend Oreille also evidenced some episodes of straying (Pratt 1992). McPhail and Baxter (1996) proposed these conflicting results could be reconciled by recognizing that bull trout spawning in large, stable streams tend to repeatedly home to them, whereas those that spawn in small streams presenting passage difficulties during episodic drought events have a greater tendency to switch streams when their home tributary is inaccessible.

Natal Homing to Parent Streams

On balance it appears that repeat homing by adult bull trout to previously used spawning sites is a relatively common occurrence. Less certain is whether bull trout exhibit fidelity to natal spawning sites that were also used by their parents. Three types of studies provide progressively stronger support for natal homing: within season homing (in which fish displaced from their spawning grounds return to it during the same spawning season); repeat (between season) homing (where adult fish that spawn at a particular location in one season, return to the same location in subsequent seasons); and "natal" homing (where juveniles marked during their first downstream emigration are recovered in the same stream during subsequent spawning migrations). Because many species of salmonids are semelparous, natal homing may be inferred by the return of marked adults to the stream the juveniles left. Because bull trout are iteroparous, return of an individual to a stream in which it previously spawned does not necessarily imply that it also returned to its natal stream because the birth stream in which it reared was not confirmed.

Genetic structuring of bull trout populations within a drainage basin suggest that genetic variability within local populations is low but genetic variation among populations is high (Costello et al. 2003; Kanda et al. 1997; Leary et al. 1993; Neraas and Spruell 2001; Taylor et al. 1999). This result is what would be expected if spawning bull trout have a high degree of fidelity to their natal tributary. Therefore, genetic data supports, or is at least consistent with, the hypothesis that bull trout have strong natal homing tendencies.

There is good evidence that Dolly Varden repeatedly home to natal tributaries to spawn. Armstrong (1974) gave anadromous Dolly Varden, captured in smolt traps during their seaward migration from three streams on Admiralty Island, Alaska, distinctive marks. None of the marked fish returning to spawn in subsequent years were captured at any location other than their stream of origin. In season and repeat homing were also demonstrated in this study. Marked adults displaced from their spawning tributary to a saltwater release site returned to the same tributary during that same spawning season (Armstrong 1974). Post spawning adults marked during their seaward migration returned with great fidelity to the same stream during subsequent spawning migrations (Armstrong 1974). Site imprinting similar to that reported for other salmonids (Scholz et al. 1976; Hasler and Scholz 1983) appears to be the mechanism by which Dolly Varden located home streams. Dolly Varden smolts, transplanted from their parent stream to a recipient stream on the last day of the smolt migration, returned to spawn in the recipient stream. These data indicated that the memory of the home stream is not inherited; rather it is rapidly acquired (i.e., imprinted) at a critical period (life stage).

It is likely that, if bull trout imprint to their natal tributary, they do so in spring either during the swimup life stage or at the time of emigration from their natal tributary. Galloway et al. (1994) and Fredenberg et al. (1998) monitored whole body thyroxine (T_4) content or circulating plasma concentration in two stocks of bull trout from the Swan River drainage, Flathead Basin, Montana at weekly or bi-weekly intervals from the day of fertilization to 983 days post-fertilization. Both stocks were adfluvial. One migrated 41-51 km up the Swan River corridor between Swan Lake and Lion Creek; the other migrated 0.2-0.5 km from an inlet tributary into Holland Lake. Both stocks exhibited recurring circannual cycles in T_4 concentration with peaks in late April and May at ages 0, 1 and 2. Thyroxine content during peaks was consistently higher in the Lion Creek stock (3.0-4.0 pg/ml basal; 8.5-9.4 pg/ml peak) which migrated long distances as compared to the Holland Lake stock (3.0-5.0 pg/ml basal; 5.9-6.7 pg/ml peak) which migrated short distances. Thyroid surges have been implicated as a mechanism for activating olfactory imprinting to natal stream odors in salmonid fishes (Scholz et al. 1976, 1985b; Johnsen and Hasler 1980; Hasler and Scholz 1983).

Adult Post-spawning Migrations

Post-spawning bull trout return to overwintering areas soon after spawning and often exhibit site fidelity to previously utilized overwinter sites. Examples include:

- Most (n = 20 of 24) fluvial bull trout tracked in the Blackfoot River, Montana exhibited fidelity to previously used overwinter sites (Swanberg 1997a). The fish left overwintering sites in June, and traveled distances up to 65 km into tributaries. Fish migrated out of tributary streams, then down the Blackfoot River and returned to within 20 meters of the site occupied in the spring. Swanberg concluded that, "*return of most bull trout to locations used before upstream migration indicated a precise homing mechanism*."
- Bull trout (n = 39 of 70) in the Morice River, British Columbia, that had migrated from overwintering sites in the main stem into spawning tributaries then made post-spawning migrations back into the main stem, returned to within ± 1 km of the same overwintering site used during the previous year (Bahr and Shrimpton 2004). These data were consistent with the hypothesis that bull trout exhibit site fidelity to overwinter areas.
- In the Athabasca River, Alberta, migration out of spawning tributaries by post-spawning adults commenced soon after spawning in September. By the end of October all the fish had moved back into the main stem Athabasca River and downstream to overwintering sites (McLeod and Clayton 1997).
- After spawning in the main stem or tributaries, radio-tagged bull trout (n = 8 of 9) in the Salmo River, British Columbia returned to the same location were they had been tagged and presumably overwintered the previous year (Baxter and Nellestijn 2000a). Five of these fish returned to overwinter in the same pools in which they were originally tagged.
- Similar behavior has been reported for bull trout in the Salmo River, Idaho (Elle and Thurow 1994), Flathead River, Montana (Block 1955; Fraley and Shepard 1989), Metolius River, Oregon (Thiesfeld et al. 1996), Salmon and Tucannon River, Washington (Martin 1992; Martin et al. 1992; Underwood et al. 1994; Underwood 1996).

Direction of Migrations

Although fluvial and adfluvial bull trout are usually envisioned as migrating downstream in a main river after leaving their spawning tributary, they can actually migrate either upstream or downstream in the main river.

- Radio-tagged bull trout, captured during their post-spawning migration in November in a trap on the Wenaha River (a tributary that enters the Grande Ronde River, Oregon at RKM 74), overwintered in the Grande Ronde River at locations both upstream and downstream from the junction of the Wenaha (Hemmingson et al. 2001, 2002). Ten fish overwintered between RKM 77-117, 12 overwintered between RKM 1-67, and two migrated out of the Grande Ronde into the Snake River as far as 35 km below the confluence. Fish that overwintered in each of these areas returned to the Wenaha from mid-April to mid-July and entered tributaries in August and September.
- Post-spawning bull trout radio-tagged in the Middle Fork East River, migrated down the East and Priest Rivers, then up the Pend Oreille River to overwinter in Lake Pend Oreille, Idaho (Geist et al. 2004; Dupont and Horner 2004). These fish returned to the Priest River from May 24 to July 1 and ascended to the Middle Fork East River by mid-July (Geist et al. 2004). Neither post-spawning outmigrants nor repeat spawning adults approached Albeni Falls Dam, which is located in the Pend Oreille River 8 km downstream (west) of the confluence of the Priest River (Geist et al. 2004). Instead, both post-spawning and pre-spawning movements were rapid and highly directed between the Priest River and Lake Pend Oreille, located 28 km up the Pend Oreille River from the confluence. These results indicated that adult bull trout from the Priest River are not very vulnerable to entrainment at Albeni Falls Dam.

Additionally, some recent investigations have blurred the distinction between fluvial and adfluvial bull trout. For example, in the Morice River system, British Columbia, bull trout that spawned in inlet tributaries of the lake passed through the lake into the outlet (Bahr and Shrimpton 2004). Although they could be considered adfluvial because they moved temporarily from a river into a lake they ultimately resided in a 'big river fluvial habitat' for most of the interval between spawning events.

Transporting Bull Trout around Dams

Bull trout entrained below dams without fish ladders will migrate upstream when transported above the dam. Examples include:

- Bull trout were blocked from spawning tributaries in the Oldman River, a tributary of the Saskatchewan River in southwestern Alberta, when Oldman Dam was constructed in 1990 without fish passage facilities. All of their prime spawning tributaries were above the dam and there were apparently no suitable spawning areas below the dam, so migratory bull trout that were entrained at the dam (or were trapped below the dam when it was closed) were lost from the spawning population. Fernet and O'Neil (1997) captured 20 fish below the dam, surgically implanted them with radiotransmitters, and released ten each above and below the dam. Of the ten fish released in the reservoir, three were later detected below the dam and seven migrated upstream into tributaries of the free-flowing segment of the Oldman River upstream of the reservoir in May to August. After spawning in September, the fish returned to the reservoir in October. The ten fish released below the dam did not spawn.
- Swanberg (1997b) monitored (by radio telemetry), in 1996, the movement of four adult bull trout captured in the tailrace and transported above Milltown Dam (RKM 364.4) on the Clark Fork River. The dam was sited at the confluence of the Clark Fork and Big Blackfoot Rivers and backs up water into both rivers. Two of the fish migrated up the Clark Fork into Rock Creek, traveling respectively distances of 40 and 130 km. At least one of these fish likely spawned. The other two fish, detected several kilometers below the dam shortly after release, later reascended to the base of the dam. Swanberg concluded that these results suggested that Milltown Dam blocked migration of fluvial bull trout in the upper Clark Fork (and probably Blackfoot) rivers and that transporting fish upstream can enhance populations, i.e., Peters et al. (1997) counted 160 bull trout redds in Rock Creek in 1996, so the addition of

these two fish may have contributed meaningful genetic information to a depressed population.

- Schmetterliing (2003) trapped 14 bull trout, 505 – 810 mm TL, below Milltown Dam in 2000 and 2001. Ten of these ascended the Big Blackfoot River (four traveled distances of 80.0, 80.4, 92.4, and 95.5 km to Monture Creek; six traveled distances of 101.1, 118.2, 127.2, 127.2, 127.2, and 129.0 km to spawn in the North Fork Blackfoot River). Three fish ascended the Clark Fork River to spawn in the Rock Creek drainage (two in the main stem at the mouths of Ranch and Hogback Creeks (after traveling distances of 47.0 and 77.4 km respectively) and one in a headwater tributary (Cooper Creek) after traveling a distance of 136.9 km. The Cooper Creek fish initially migrated 39.8 km up the Blackfoot River before reversing direction, returning to the reservoir, then migrating up the Clark Fork to Rock and Cooper Creeks. Redds were found near the two bull trout in Cooper and Hogback Creeks (Clark Fork River drainage) and three that migrated 127.2 – 129.0 km into the North Fork (Blackfoot River drainage). Only five fish were located after the spawning season. Four migrated back to the reservoir and three of them fell back over the dam and moved up to 50 km below it (one migrated back to the base of the dam the following spring but did not enter the trap). The fifth fish remained in an isolated pool in the North Fork Blackfoot River. Apparently, extreme drought conditions in 2001 prevented post-spawning migrations of fish at some locations. Schmetterling (2003) concluded that, because the number of bull trout spawners in the Clark Fork and Blackfoot Rivers above Milltown Dam is low (some tributaries support fewer than 50 spawning adults), transport of adults around the dam can augment the spawning population and provide immediate genetic benefits to depressed upriver populations.

Tenacity of Migratory Bull Trout

Bull trout have a "*remarkable ability to squirm over barriers*" (McPhail and Baxter 1996) and have been documented to surmount barriers that block rainbow trout (McPhail and Murray 1979). During upstream spawning migration bull trout can traverse waterfalls, log jams, cascades and other obstacles that are barriers to salmon and steelhead (Brown 1994; Kramer 1990).

Biotelemetry investigations in the Kootenai River, Montana demonstrated that a bull trout successfully ascended the 30 foot high Kootenai Falls (Dunnigan et al. 2003; Hoffman et al. 2002). A post-spawning female bull trout, radio-tagging as an outmigrant in Quartz Creek on October 7, 1999, migrated into the Kootenai River and then traveled downstream below Kootenai Falls on November 4, 1999 (Hoffman et al. 2002). It remained below the falls until July 18, 2000. When next detected on September 27, 2000 it had ascended above the falls. From September 18, 2000 through September 27, 2000 it migrated into Quartz Creek and was presumed to have spawned there a second time (Dunnigan et al. 2003). After spawning the fish migrated back into the Kootenai River between September 27, 2000 and November 6, 2000 and remained above the falls before returning to Quartz Creek a third time between August 20, 2001 and September 24, 2001 (Dunnigan et al. 2003).

The Kootenai River drops 24.7 m over a distance of 1.6 km through China Rapids and a series of limestone ledges. The largest of these, Kootenai Falls, is roughly 9.1 m high (depending upon the river stage). It was assumed that Kootenai Falls was a formidable (and complete) barrier to fish migration until these data became available. The authors concluded, "*This was the first recorded instance of a fish migration upstream over the falls; therefore the falls is not a barrier to all upstream migration, though it does serve as a migration impediment*" (Hoffman et al. 2002).

Purpose of Migration

Migratory forms of bull trout probably evolved because they place individuals in locations where there is a better opportunity for growth and gamete production in comparison to resident forms that live permanently in cold, unproductive headwater tributaries. Although spawning populations of bull trout tend to be naturally isolated from one another because of the tendency of individuals to return to spawn in a home stream (which promotes adaptation to the environment on a local scale as well as genotypic and phenotypic distinctiveness among local populations), occasional straying by migratory bull trout contributes to genetic exchange between populations and makes local populations more vigorous (resilient) by increasing genetic variability and diversity. This results in a metapopulation structure at a regional scale. Thus, the diversity of bull trout life history strategies plays a key role in their metapopulation structure and their persistence as a species (Bergdahl 1998; Northcote 1992; Rieman and McIntyre 1996).

At local scales, individual bull trout populations are at risk of local extirpations owing to habitat degradation (e.g., by deforestation), environmental stochasticity (e.g., catastrophic fires or drought events that reduce stream discharge), genetic risks (e.g., those associated with small population size such as inbreeding depression) and interaction with non-indigenous fishes [e.g., hybridization with brook trout, *Salvelinus fontinalis* (Kitano et al. 1994; Leary et al. 1983; Martin 1992), or competition with lake trout, *Salvelinus namaycush* (Donald and Alger 1993)].

At a regional scale bull trout metapopulations are at risk of species extinction because their local populations are becoming increasingly isolated in shrinking patches of habitat as migration corridors of fluvial and adfluvial populations have become blocked by construction of hydroelectric and irrigation dams (Lacy 1987; Rieman and McIntyre 1993, 1995, 1996; Rieman et al. 1997; Thurow et al. 1997; Dunham and Rieman 1999). Dam construction has fragmented the regional metapopulation structure of bull trout in many subbasins of the Columbia River, particularly in the Pend Oreille/Clark Fork System where construction of nine dams on the main stem has isolated segments of the regional populations.

Rieman and McIntyre (1996) have pointed out that the persistence of bull trout at both local and regional scales will likely require restoring the connectivity (i.e. metapopulation structure) between local populations. Reestablishment of migration corridors would allow individuals, whose contribution to locally adapted gene pools would have been lost because their access to home tributaries was blocked, to contribute genetic variation that helps make the gene pool of their parent stock more robust. Reestablishment of migration corridors would also likely promote increased wandering and straying by migratory bull trout, which provides a mechanism to recolonize damaged habitat or increase the genetic diversity of small, isolated, genetically depressed populations.

In the Boise River Basin, stream segments where bull trout had been eradicated by forest fires were found to be repopulated several years later. Large bull trout were observed in these streams following the fire, suggesting that repopulation was facilitated by either migratory fish that had survived the inferno in another part of the watershed and had homed back to their natal site or migratory bull trout that had strayed into the vacant habitat and spawned (Rieman et al. 1997; Thurow et al. 1997).

Rieman et al. (1997) examined 4,462 watersheds in the Pacific Northwest and noted that in most of them migratory bull trout life histories had been lost entirely or their mobility was greatly restricted from the historic past owing to dam construction. They concluded that the present situation of restricted mobility was probably a limiting factor that prevented local populations suffering habitat loss to recover (because their depressed populations were genetically weakened and they had no means of increasing genetic variation in the remaining population as there was no immigration). Dams eliminate or restrict upstream migration of adults, affecting the ability of fish to reproduce in their natal tributary (Rieman and McIntyre 1995; Swanberg 1997b).

Spawning Habitat

Throughout their range bull trout spawn in small tributaries and typically construct redds in proximity to areas of groundwater upwelling and presence of cover (Needham and Vaughan 1952; Heimer 1965; Leggett 1969; Shepard et al. 1984; Fraley and Shepard 1989; Martin 1992; Martin et al. 1992; Goetz 1994; Underwood et al. 1994; McPhail and Baxter 1996; Underwood 1996; Baxter 1997; Baxter et al. 1997; James and Sexauer 1997; Baxter and McPhail 1999). Bull trout are sensitive indicators of deforestation. Reduction in the forest canopy of a watershed is associated with greater (and earlier) runoff and less groundwater infiltration, which may result in: 1) reduced stream discharge during the critical late summer low flow period; 2) reduced percolation of cold ground water into streams during the warm summer months; and 3) fewer sites of groundwater upwelling that are preferred areas of spawning by bull trout.

Redd Counts

Redd counts underestimate bull trout spawning escapement because several fish may spawn in the same redd. For example, Block (1955) saw a male bull trout spawn on the same redd with three different females in succession; the size of the redd expanded with each spawning event. Kramer (1990) reported that a single female was courted by three males and spawned with each of them on the same redd. Fraley and Shepard (1989) counted adults caught in migration traps and compared these counts to the number of redds observed and found that an average of 3.2 spawners entered the tributary for each redd observed. A similar study in Washington indicated an average of 2.2 spawners per redd (Mongillo 1993). A range in spawning escapement can be estimated (expanded) by multiplying the redd count by these numbers (ratios), and most expansions to date have used these values.

However, recent studies indicated that fewer or more adults may be represented per redd. In Idaho, 53 adult bull trout transported above a migration barrier in Johnson Creek (tributary of Lake Pend Oreille) constructed 33 redds (1:6 spawning adults per redd) (Downs et al. 2003). In Rattle Creek, a tributary of Lightning Creek (Lake Pend Oreille tributary, 102 adult bull trout counted during snorkeling surveys produced 67 redds, a ratio of 1.5 adults per redd (Downs et al. 2003). Adult bull trout populations, estimated by mark-recapture methods and redd counts were made in four tributaries of Lake Pend Oreille in 2000 (Downs et al. 2003). Adult spawners to redd ratios ranged from 1.4 – 3.7 (Table A1).

Table A1. Estimated bull trout populations, redd counts and adult: redd ratios for four tributaries of Lake Pend Oreille in 2000 (After Downs et al. 2003).

Tributary	Population estimate			# redds counted	Adult: redd ratio
	N =	Lower 95% CI	Upper 95% CI		
E. Fork Lightning Cr.[1]	75	48	204	54	1.4:1
Grouse Cr.	224	183	293	77	2.9:1
Gold Cr.	313	201	636	168	1.9:1
Trestle Cr.	1,114	894	1,334	301	3.7:1

[1] Adult:redd ratio may actually be smaller than 1.4:1 because some of fish from East Fork Lightning Creek may have spawned in tributaries.

Summary of and Inferences from Life History Information

Bull trout are intolerant of water > 18.5 °C and prefer water ≤ 15 °C (Goetz 1989; McPhail and Baxter 1996). Numerous investigators have reported that bull trout are relatively early spawners (late August – early October) and that they are attracted to areas of groundwater upwelling as preferred spawning habitat (e.g., Pratt 1985; Goetz 1989; McPhail and Baxter 1996). In addition to its benefits associated with incubation, upwelling groundwater may provide bull trout with distinctive odors to which the juvenile bull trout becomes imprinted. These odors may later serve as a cue to direct mature fish to natal spawning sites. The bull trout appears to be a key indicator species. Local population are sensitive to land use practices, especially those that reduce stream discharge during the end of the summer when annual water temperatures are highest and bull trout are seeking natal cold upwelling ground water areas in which to spawn. Factors that promote early runoff (such as clear cut logging), or take water over the course of summer (such as irrigation withdrawals), may reduce cold ground water inflow during this critical late summer period. This could potentially adversely affect bull trout survival and spawning success and lead to their rapid disappearance at the local level.

In nature, development of the migratory life history variant allowed bull trout to survive catastrophes that depleted local resident populations, i.e., it provided a mechanism to restore depleted populations.

Migratory bull trout appear to have a strong homing tendency and repeatedly return to a previously used spawning tributary. Molecular genetic (protein and DNA) investigations indicated that genetic variation in bull trout is low in individuals from a population in one tributary but high among populations from different tributaries. This result is what would be expected if bull trout have a high degree of fidelity to their natal tributary. Thus, genetic data supported the hypothesis that bull trout have strong natal homing tendencies. Bull trout also usually return to previously occupied ‘overwinter’ or ‘maturation’ sites soon after spawning. In their migrations between home spawning tributaries and maturation areas, migratory bull trout exhibit remarkable fidelity to each locale.

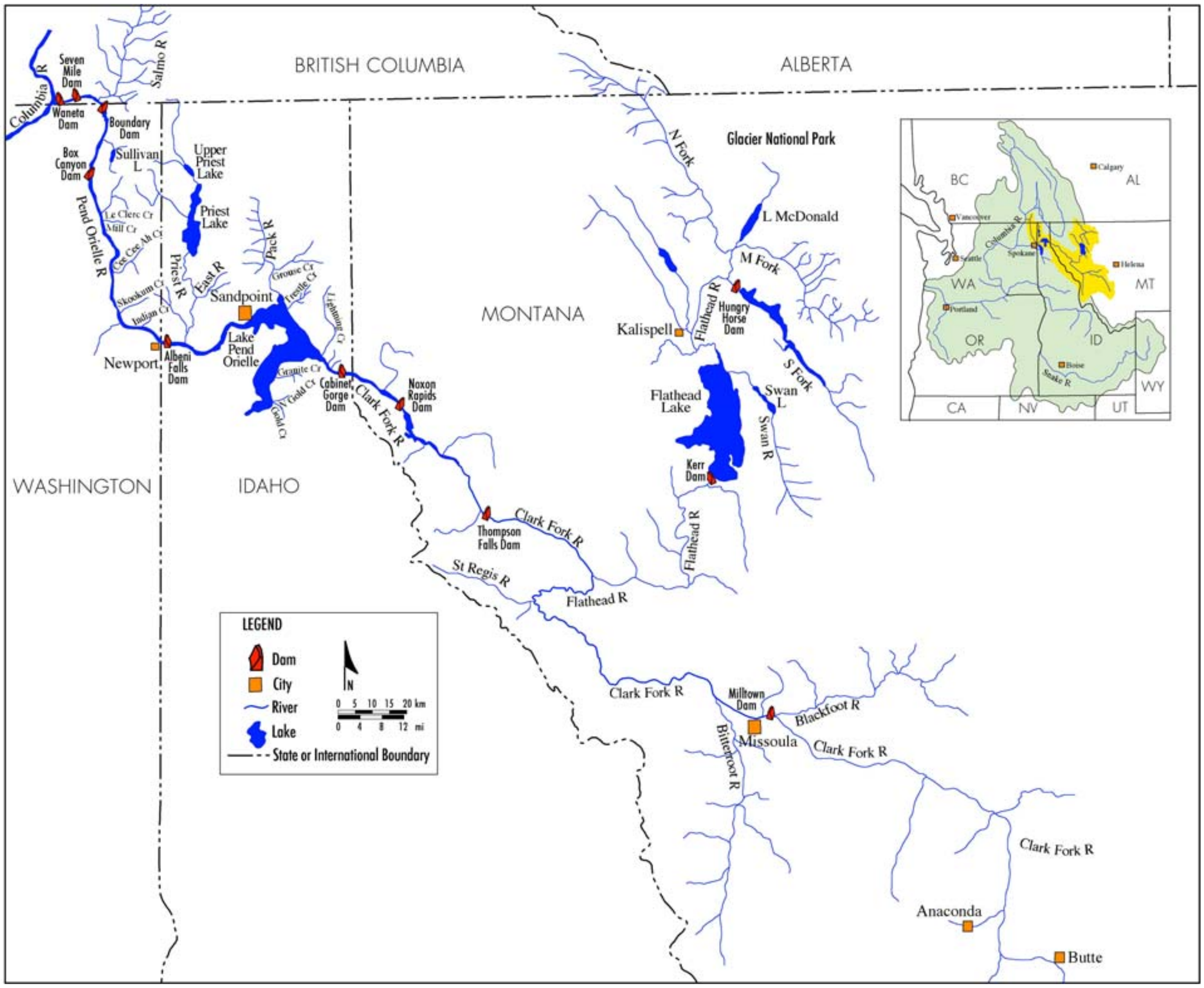
Fragmentation of migration corridors, by permanent blockages caused by construction of hydroelectric/irrigation dams without fish ladders, or by temporary blockages caused when irrigation withdrawals dewater river segments (especially during drought), are major threats to the continued existence of migratory bull trout. Moreover, populations being depleted at local levels are unable to be restored if access of the migratory variant to those areas is blocked. Epifanio et al. (2004), investigating bull trout in the Pend Oreille/Clark Fork Basin, concluded that, "*Reestablishing connectivity by restoring upstream passage of fish blocked by dams represented the single most important mechanism to reduce the risk of a genetic bottleneck (reduced genetic variation and inbreeding associated with depleted populations).*"

The preciseness of their movements (noted in numerous radio tracking and tagging investigations) makes it especially important that every adfluvial or fluvial bull trout spawning in a depleted population be given opportunity to home to its spawning tributary because it isn't likely that an individual straying from another tributary will come along to replace it. Thus, loss of a fish from a depleted spawning population will result in a loss of genetic diversity (alleles) in the population and a loss of reproductive potential because the gametes of a large, fecund individual will not be contributed to the population.

Bull Trout in the Pend Oreille/Clark Fork River Basin

The Pend Oreille/Clark Fork River system flows 789.1 km (490.4 miles) from its source near Butte, Montana, in a northwesternly direction through Montana, Idaho, Washington and British Columbia to its confluence with the Columbia River (Columbia RKM 1199.5, left bank) (Figure A1). The drainage area of the Pend Oreille/Clark Fork sub-basin (66,822 km^2) comprises 10 percent of the Columbia River Basin (668,220 km^2) (Hydrology and Hydraulics Subcommittee 1976). The river segments include 25.7 km in British Columbia (RKM 0-25.7), 166.2 km in Washington (RKM 25.7-141.9), 99.4 km in Idaho (RKM 141.9-241.3), and 548.7 km in Montana (RKM 241.3-789.1) (Hydrology and Hydraulics Subcommittee 1976).

Figure A1. Pend Oreille River Basin indicating locations of principle rivers, lakes, and main stem dams. Inset map shows Columbia River Basin with Pend Oreille/Clark Fork sub-basin highlighted in yellow.



Principle tributaries include: Salmo River, British Columbia (RKM 21.4, right bank), Priest River, Idaho (RKM 153.2, right bank), Flathead River, Montana (RKM 394.2, right bank), Bitterroot River, Montana (RKM 586.6, right bank) (Hydrology and Hydraulics Committee 1976). The Clark Fork River forms the principle inlet of Lake Pend Oreille, Idaho (RKM 223), and the Pend Oreille River is the lake's outlet (RKM 191.5). Albeni Falls Dam, located 28.9 km below the lake's outlet backs up water in the Pend Oreille River, Lake Pend Oreille and lower 16.9 km of the Clark Fork River to a surface elevation of 628.5 m.

Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) ascended the Pend Oreille River at least as far as the Z-Canyon at RKM 29-36.5 (Bryant and Parkhurst 1950; Fulton 1968, 1970; Gilbert and Evermann 1895; Scholz et al. 1985a). Salmon and steelhead passed over a 3 m high waterfall near the mouth of the Pend Oreille River (RKM 0.5) to spawn near the confluence of the Pend Oreille and Salmo Rivers. How many, if any, passed above the Z-Canyon is uncertain. It is usually assumed (by hindsight and without the benefit of physical inspection of the canyon in its natural state) that the turbulent whitewater of the Z-Canyon formed a velocity barrier which prevented the ascent of salmon and steelhead. However, Charles Gilbert and Barton Evermann (1895) surveyed the entire length of the river between Albeni Falls and the international boundary by steamboat and foot for the explicit purpose of assessing obstructions to fish migration. In particular, they examined Albeni Falls (RKM 145.0), the Box Canyon (RKM 55.0), Metaline Falls (RKM 43.0) and the Z-Canyon (RKM 29-36.5) and concluded that none of them represented a serious obstacle to fish migration.

Gilbert and Evermann (1895) visited the Z-Canyon (which was also called Big Eddy Cañon) on August 10, 1894 and related that the full fury of the Pend Oreille River passed through a narrow gorge about 4.8 km in length with vertical walls so close together "*that in one place a fallen tree lies across from one wall to the other. The river rushes through this cañon with great fury, but there are no falls, and we do not believe the ascent of the salmon would be seriously interfered with. If it should be shown that salmon cannot swim against such a strong current for so great a distance, we see no easy way by which it could be made less difficult. There are some relatively quiet nooks and eddies here and there, however, in which a salmon would be able to rest and we therefore do not consider Big Eddy Cañon a serious obstacle to the ascent of fish*."

Gilbert and Evermann (1895) also reported that salmon "*could probably ascend* [Metaline Falls] *without much difficulty*" because, although the river fell 30 ft, it was over a series of limestone ledges "*in a series of rapids, there being no vertical drop at all*." At Box Canyon there was "*nothing to stop the ascent of salmon*". The falls at the current site of Albeni Falls Dam was not a passage barrier. "*These falls* [were] *scarcely more than a pretty steep rapid and would not interfere at all with the ascent of salmon,"* (Gilbert and

Evermann 1895). Rathbun (1895) observed that trout (species not indicated) "*pass freely up the falls*."

Over its course, the Pend Oreille/Clark Fork River is now impounded by nine main stem dams: Waneta and Seven Mile in British Columbia, Boundary and Box Canyon in Washington, Albeni Falls and Cabinet Gorge in Idaho, and Noxon Rapids, Thompson Falls and Milltown in Montana. Each of these dams fragmented and isolated a portion of the bull trout metapopulation in the Pend Oreille/Clark Fork Basin because none of them were constructed with fish ladders. Locations of each dam and the year it blocked migratory bull trout are described in Table A2. A synopsis about what is known about bull trout populations in each of these fragmented regions is described below.

Table A2. Location [distance above the mouth in river miles (RM) and river kilometers (RKM)], year that the dam became operational (blocked fish passage), and current operators of nine main stem dams in the Clark Fork/Pend Oreille River Basin.

Main stem Dam	RM	RKM	Blocked fish migration in	Dam height (m)	Reservoir length (km)	Current operator
Waneta	0.5	0.8	1954	76.0	10.0	Tekcominco
Seven Mile	6.0	9.7	1980	67.0	19.5	BC Hydro
Boundary	17.0	27.4	1967	104.0	28.1	Seattle City Light
Box Canyon	34.5	55.5	1956	30.5	89.8	Pend Oreille Co. PUD
Albeni Falls	90.1	145.01	1952	19.8	77.3	U.S. Army, Corps of Engineers
Cabinet Gorge	149.9	241.2	1952	48.7	32.2	Avista Utilities
Noxon Rapids	169.7	273.1	1960	79.3	61.1	Avista Utilities
Thompson Falls	208.0	334.7	1913	16.5	19.3	Montana Power
Milltown	364.4	586.3	1907	6.0		Northwestern Power Company

Waneta Reservoir

Waneta Dam (approx. 76 m high at RKM 0.8) was completed in 1954, owned by Tekcominco, Ltd. Power production is coordinated by contractual arrangement with B.C. Hydro. The dam is operated as part of the West Kootenay Power System. Power generated by this dam supports smelting and industrial operations at the Cominco Smelter in Trail, British Columbia (Hirst 1991). Waneta reservoir is relatively short (about 8 km) with one permanent tributary (Cedar Creek).

Fish surveys in Waneta Reservoir were described by Hirst (1991), Hildebrand (1992) and R.L. & L. Environmental Services (R.L. & L.) (1994b, 1995a, 1996, 1999). No bull trout were captured in Waneta Reservoir during a gill net survey conducted in 1994 (Hirst 1991). Hildebrand (1992) recorded three bull trout from Waneta Reservoir. Six bull trout were captured in a sample of 113,000 fish collected by electrofishing and gill netting in Waneta Reservoir between 1990 and 1993 (R.L. & L. 1994b) but none were caught in a sample of 2,736 fish collected there in 1994 (R.L. & L. 1994a, 1995a). Four of the six bull trout captured in the 1990-1993 survey were caught at the mouth of Cedar Creek. Three additional bull trout were recorded near Cedar Creek by R.L. & L. (1996). Tributary backpack electrofishing in Cedar Creek failed to produce any bull trout. Collectively, these reports suggest that bull trout in Waneta Reservoir were dropouts from upriver. Bull trout were concentrated near Cedar Creek probably because it offered a cold water refuge.

Seven Mile Reservoir (includes Salmo River)

Seven Mile Dam (approx. 67 m high at RKM 9.7) was completed in 1978 and became operational in 1979. The reservoir extends 19.5 km and backs up the Pend Oreille River to the international boundary. Eight tributaries enter the reservoir. Seven Mile Reservoir provided a viable sport fishery for bull trout (R.L. & L. 1999). The Salmo River joins the Pend Oreille on the right bank at RKM 21.4. The Salmo is 39 miles (62.8 km) long with nine tributaries. The Salmo is a stronghold for bull trout in the lower Pend Oreille Basin.

Fish surveys in Seven Mile Reservoir were described by BC Hydro (1991), Hirst (1991) and R.L. & L. (1994a, 1995b, 1999, 2001). Bull trout were known to be present in the Seven Mile Reach prior to construction of the dam but none were collected in a sample of 316 fish representing eight species were collected during gill net sampling in 1987 (BC Hydro 1991; Hirst 1991). Four bull trout were caught in a sample of 25,725 total fish collected by electrofishing and gill netting from September 1994 to June 1995 (R.L. & L. 1994a, 1995b). Three juvenile bull trout, 151-240 mm TL, were caught in a sample of 18,544 fish collected during seasonal electrofishing surveys conducted in August and November 1999, and March and June 2000 (R.L.& L. 2001). Two of these were collected near the mouth of the Salmo River and one was collected in the forebay. Seven tributaries of Seven Mile Reservoir were sampled by backpack electrofishing in the 1999/2000 survey. Six bull trout were captured in a sample of 87 total fish. Bull trout were captured in two tributaries: Nine Mile Creek (n = 5 of 17 total fish) at RKM 10.8 (right bank) and Harcourt Creek (n = 1 of 5 total fish) at RKM 17.4 (left bank).

Fish surveys were conducted in the Salmo River and its tributaries (by Baxter et al. 1998; Baxter and Nellistijn 2000a, 2000b; Baxter and Baxter 2003; Baxter 2004; reviewed by BC Hydro 1991; R.L & L. 1999, 2001). In 1974, a snorkel survey recorded ten bull trout (4.6 percent) in a sample of 210 fish observed in the lower 16.1 km of the Salmo River (BC Hydro 1991). In 1988, six bull trout were recorded in a sample of 2,659 fish observed during two snorkel surveys (July and September) in the lower 10 km of the Salmo River (BC Hydro 1991). In 1997 electrofishing surveys were conducted at eight locations in the Salmo main stem and 20 locations in nine tributaries (Baxter et al. 1998). Bull trout populations were estimated by the three pass removal method and densities determined. A total of 23.2 hours was electrofishing effort was expended to sample an area of 6638.2 m^2 (Baxter et al. 1998). A total of 1,179 fish, representing six species were capture during these surveys, including 206 juvenile bull trout (17.6 percent relative abundance) that ranged from 44-263 mm TL and 0-3 in age (Baxter et al. 1998). Table A3 provides a summary of the data collected by tributary.

Table A3. Summary of bull trout collected during 1997 survey of the Salmo River and its tributaries (data from Baxter et al. 1998). RKM denotes point of confluence with Salmo River, South Salmo River (*) or Sheep Creek (t) L = left bank; R = right bank.

RKM	Location	# Sites surveyed (n)	Total # fish	# bull trout	Mean density (#bull trout/m^2)	Range in density (# bull trout/m^2)
0-62.9	Salmo River	8	322	103	6.6	0.0-14.3
11.9 (L)	South Salmo	5	228	33	3.1	0.3-6.6
2.3 (*)	Lost Creek	1	35	8	2.9	2.9
11.3 (*)	Stagleap Creek	1	65	12	3.4	3.4
21.7 (L)	Sheep Creek	4	84	19	2.7	0.0-7.6
8.5 (t)	Waldie Creek	1	27	2	0.4	0.4
28.6 (R)	Erie Creek	1	244	0	0	0
43.6 (L)	Ymir Creek	1	94	0	0	0
54.6 (R)	Hall	1	8	2	1.4	1.4
59.4 (L)	Clearwater	4	72	27	5.0	0.0-10.8

During these surveys 36 sexually mature bull trout (506 ± 17 mm, n = 27) and 28 redds were observed in four streams: Salmo River main stem (n = 7 redds), Sheep Creek (n = 12), and Clearwater Creek (n = 9). Redds were not observed in Waldie Creek, South Fork Salmo River, Lost Creek of Stagleap Creek, but concurrent biotelemetry investigations indicated use of those streams by spawning adults (Baxter et al. 1988). Bull trout spawning escapement in the Salmo watershed was estimated at 84 adults (Baxter et al. 1998).

In snorkel surveys conducted in 1999 and 2000 between RKM 12.2-27.4 of the Salmo main stem, Baxter and Nellistijn (2000b) counted 10 bull trout < 300 mm TL and 92 bull trout > 300 mm TL. In 2003, 83 bull trout < 300 mm and 122 bull trout were observed in a similar survey (Baxter 2004). In 2003, bull trout redds were observed in the upper Salmo main stem (n = 21), south Salmo River (n = 15), Clearwater Creek (n = 22), and Sheep Creek (n = 47) but not in Stagleap Creek (Baxter 2004). Bull trout spawning escapement in the Salmo watershed ranged from 119-185 adults from 1988-2002 (Baxter and Baxter 2003) and was 196 in 2003 (Baxter 2004) (Table A4). Legal harvest of bull trout was allowed in the Salmo Basin until 1999 (Adonaegui 2003). Increased redd counts in 2003 may be partly related to cessation of harvest.

Table A4. Estimated bull trout escapement in Salmo River drainage, 1988 – 2003. (After Baxter 2004).

Location	Estimated bull trout escapement in					
	1998	1999	2000	2001	2002	2003
Upper Salmo River	23	19	47	25	32	49
South Salmo River	50	34	52	42	39	26
Clearwater Creek	36	29	37	40	11	40
Sheep Creek	70	41	50	41	38	82
Total	180	123	185	147	119	196

The United States Forest Service found bull trout in the South Fork Salmo River, in a segment of the stream in the Colville National Forest (R.L. & L. 1999). In 2002, bull trout genetics sampled were collected from various locations in the Salmo drainage:

Salmo River main stem (n = 30), Upper Salmo River (n = 33), South Salmo River (n = 50), Clearwater Creek (n = 31), and Sheep Creek (n = 33) (Maroney et al. 2003).

Boundary Reservoir

Boundary Dam (approx. 104 m high at RKM 27.4), constructed in 1965, impounded a 28 km long reservoir that inundated the Z-Canyon. Ten tributaries enter Boundary Reservoir.

Fish surveys were performed in Boundary Reservoir by Peck (1982), Cascade Environmental Service (1996), R2 Resource Consultants (1998), and McLellan (2001). The Washington Department of Fish and Wildlife found no bull trout in a sample of 59 fish collected by gill netting at the mouths of Sand (n = 25) and Sweet (n = 34) Creeks in 1982 (Peck 1982). In 1996 and 1997, traps were set in the reservoir at the mouths of selected tributaries (R2 Resource Consultants 1998). These traps, set for a total of 5,392 hours in 1996 and 1,105 hours in 1997, caught seven fish, including one bull trout at the mouth of Slate Creek in 1996 (R2 Resources Consultants 1998). Creel surveys conducted on 17 days in 1997 determined that anglers caught 455 fish, representing 11 species, but no bull trout (R2 Resource Consultants 1998). In 2000, electrofishing and gill net surveys conducted by the Washington Department of Fish and Wildlife resulted in the capture of 1,822 fish representing 18 species but no bull trout (McLellan 2001).

Seven tributaries of Boundary Reservoir have been surveyed for bull trout by snorkeling and/or backpack electrofishing (Cascade Environmental Service 1996; McLellan 2001; Pend Oreille County PUD 2000). The most comprehensive survey was performed by WDFW in 2000 (McLellan 2001) when all seven tributaries were surveyed at randomly selected sites (total for all tributaries = 139) along their length. A total of 1,039 fish were observed, including one bull trout, 300 mm TL, in Sweet Creek. Data for individual tributaries is recorded in Table A5.

In addition, the United States Forest Service (USFS) collected 79 fish in Sand Creek (0 bull trout) in 1992 (Pend Oreille County PUD 2000). In 1996 and 1997, the USFS conducted snorkel and electrofishing surveys in Flume, Sand, Slate (including tributaries of Slate Creek – Slumber, Styx and Uncas Gulch Creeks), Sullivan and Sweet Creeks. A total of 527 fish (0 bull trout) were observed during snorkel surveys and 186 fish (0 bull trout) examined during electrofishing surveys in these drainages (Pend Oreille County PUD 2000).

Table A5. Summary of WDFW 2000 survey of tributaries of Boundary Reservoir (data from McLellan 2001). RKM denotes point of confluence with Pend Oreille River or Sweet Creek (*). L = left bank, R = right bank.

RKM	Location	# Sites surveyed (n)	Total # fish	# Bull trout
29.0 (L)	Pee wee Creek	6	5	0
30.7 (R)	Lime Creek	8	35	0
35.7 (R)	Slate Creek	24	157	0
41.5 (L)	Flume Creek	13	165	0
43.3 (R)	Sullivan Creek	55	430	0
49.7 (L)	Sweet Creek	14	167	1
*	Lunch Creek (trib. Sweet Cr.)	7	15	0
50.8 (R)	Sand Creek	12	65	0

The most intensively surveyed drainage was Sullivan Creek. Data collected by the Washington Water Power Company in 1979, Tera Corportation in 1991, United States Forest Service in 1993-1994, Pend Oreille County PUD from 1993-1996, and Cascade Environmental Services in 1995 was summarized by Pend Oreille County PUD (2000). Collectively 5,500 fish were caught or observed and no bull trout were detected. The study by Cascade Environmental Services was specifically designed to detect the presence or absence of bull trout; none were recorded in a sample of 1,076 fish. An employee of Cascade Environmental Services (1996) observed a large (757 mm) bull trout dead on the bank of Sullivan Creek about 0.5 km above its confluence with the Pend Oreille River in 1993 and assumed it had been discarded there by an angler.

The fish population in Sullivan Lake was surveyed in 1990 by the Washington Water Power (WWP) Company, in 1994 by WDFW (Mongillo and Hallock 1995) and in 2003 by Eastern Washington University (Nine 2005). WWP caught 261 fish in a gillnet survey but no bull trout. WDFW caught 74 fish in a gillnet survey but no bull trout (Mongillo and Hallock 1995). In 2003, surveys were conducted at monthly intervals from April to November. A total of 3,279 fish representing 11 species were captured during 15.2 total hours of electrofishing and 72 gillnet sets (Nine 2005). No bull trout were caught. Additionally, Nine (2005) sampled the lower 0.5-1.0 km of the lake's two inlets Harvey Creek and Noisy Creek, by backpack electrofishing. No bull trout were collected in a sample of 67 fish from Harvey Creek and 143 fish from Noisy Creek. Eighteen sites were sampled in the Harvey Creek drainages by the Kalispel Tribe in 2003 (Conner et al. 2003b). No bull trout were observed.

Box Canyon Reservoir

Box Canyon Dam (approx. 30.5 m high at RKM 55.5), completed in 1956, was the first publicly owned dam in Washington. It impounded 90 km (55.7 miles) of the Pend Oreille River. Twenty-two tributaries enter Box Canyon Reservoir.

Bull trout were once abundant in the Box Canyon Reach of the Pend Oreille River (Gilbert and Evermann 1895; Jordan and Evermann 1908). At the mouth of LeClerc Creek, a bull trout 660 mm long and weighing 1.9 kg was seen in the possession of a Kalispel Indian (Gilbert and Evermann 1895). Jordan and Evermann (1908) identified the Box Canyon Reach as one of the nations premiere bull trout waters: "*It has been our pleasure to fish for Dolly Varden (i.e., bull trout) in many different waters, among which we recall with particular satisfaction the Pend d'Oreille River from the Great Northern Railroad to the international boundary…*" Gilbert and Evermann (1895) described the waters in this reach as, "*clear and pure and cold – an ideal trout stream*," and noted "*trout* [i.e., cutthroat trout] *are abundant in this river; salmon trout* [i.e., identified as bull trout in the taxonomy section of their report] *are also quite abundant… We know of no stream which offers finer opportunities for sport with rod and reel than the lower Pend d'Oreille* [i.e., the section between Albeni Falls and the international boundary]."

Apparently, bull trout persisted in good numbers throughout the Box Canyon Reach until the 1950's because "*many large Dolly Varden* [bull trout]" were caught during a Field and Stream tournament held on the Pend Oreille River in 1957 (Metaline Falls Gazette, April 3, 1958).

Most of the old growth timber in the Pend Oreille Valley, Washington was logged off between 1915 and 1930. Catastrophic fires during this time frame further denuded the landscape. Sediments, eroded off deforested hillsides, became embedded in the gravel bottoms of spawning tributaries. Log chutes and splash dams were used to move logs down tributaries to lumber mills on the main stem. Non-indigenous fish, such as largemouth bass (*Micropterus salmoides*) and brook trout (*Salvelinus fontinalis*) that could potentially prey on, compete with or hybridize with indigenous salmonids, were introduced initially by the U.S. Fish Commission and its progeny (U.S. Bureau of Fisheries), and later by the U.S. Forest Service, Pend Oreille County Fish and Wildlife Commission, and Washington Department of Fish and Wildlife. All of these factors contributed to the decline of native salmonids, but construction of hydroelectric dams (Albeni Falls in 1952 and Box Canyon in 1956) transformed the Pend Oreille River by inundating habitat, increasing water temperature, and blocking migratory corridors of fluvial and adfluvial species. Population declines of bull trout appeared to accelerate following construction of these dams (U.S. Fish and Wildlife Service 2000).

Box Canyon Reservoir was surveyed by Barber et al. (1989a, 1989b, 1989c, 1990), Bennett et al. (1990), Ashe (1991), Ashe et al. (1991a, 1991b), Bennett and Liter (1991), Ashe and Scholz (1992), Skillingstad (1993) and Skillingstad et al. (1993), Bennett and Garrett (1994), KNRD and WDFW (1996, 1997, 1998), Scholz (1998), Anderson (2000, 2002), Anderson and Olson (2003), Conner et al. (2003a, 2003b), Olson and Anderson (2004) and Geist et al. (2004), Divens (2005).

Surveys were made by Eastern Washington University (EWU) in 1987, 1988, 1989, 1990, 1991-1992 and 1997. The surveys in 1989, 1990 and 1991-1992 surveyed the entire reservoir (RKM 55.5-145.0) at monthly intervals (March to November) whereas those in 1988, 1991-1992 and 1997 were limited in scope and focused on a 12.2 km segment between Cee Cee Ah Creek (RKM 105.7) and Skookum Creek (RKM 117.9). See Ashe and Scholz (1992) for a complete summary of the reservoir wide survey data set.

- In 1987, one bull trout was captured in a sample of 5,652 fish in 20.2 hours of electrofishing (Barber et al. 1989a). Bull trout relative abundance was 0.02

percent and CPUE was 0.05 bull trout per hour. The bull trout was captured near the mouth of Indian Creek in September.

- In 1988, one bull trout was captured in a sample of 19,931 fish in 54.3 hours of electrofishing (Barber et al. 1989b, 1989c; Ashe and Scholz 1992). Relative abundance was 0.005 percent and CPUE was 0.02 bull trout per hour. The bull trout was captured at the mouth of LeClerc Creek in September. No bull trout were captured in either gill net surveys (n = 264 fish in 393 hours of net soak time) or beach seine surveys (n = 3,407 fish in 1.4 km of hauls).
- In 1989, two bull trout were captured in a sample of 17,554 fish in 90.5 hours of electrofishing (Barber et al. 1990; Ashe and Scholz 1992). Relative abundance was 0.01 percent and CPUE was 0.02 bull trout per hour. The bull trout were captured at the mouths of Cee Cee Ah Creek and Skookum Creek in September. No bull trout were captured in either gill net surveys (n = 75 fish in 318 hours of net soak time) or beach seine surveys (n = 805 fish in 0.7 km of hauls).
- In 1990, one bull trout was captured in a sample of 9,933 fish in 71.4 hours of electrofishing (Ashe 1991; Ashe et al. 1991a, 1991b; Ashe and Scholz 1992). Relative abundance was 0.01 percent and CPUE was 0.01 bull trout per hour. The bull trout was captured near the mouth of Cee Cee Ah Creek in June. No bull trout were captured in either gill net surveys (n = 67 fish in 54 hours of net soak time) or beach seine surveys (n = 517 in 0.5 km of hauls).
- From August 1991 to July 1992, no bull trout were captured in a sample of 5,139 fish in 27.0 hours of electrofishing (Skillingstad 1993; Skillingstad et al. 1993). No bull trout were captured in either gill net surveys (n = 256 fish in 154 hours of net soak time) or beach seine surveys (n = 777 fish in 1.1 km of seine hauls).
- In 1997, no bull trout were captured in a sample of 730 fish collected in 3.0 hours of electrofishing on four dates in April and July (Scholz 1998).

The University of Idaho sampled Box Canyon Reservoir by electrofishing, gillnetting and beach seining in 1989 and 1990 (Bennett and Liter 1991). In 1989, one bull trout was captured in a sample of 15,887 fish (Bennett and Liter 1991). In 1990, one bull trout was captured in a sample of 13,326 fish (Bennett and Liter 1991). The capture locations of the bull trout were not listed in their report.

The Kalispel Tribe has done extensive electrofishing in Box Canyon Reservoir since 1997 and has not found any bull trout (Stovall et al. 2001). From 1997 to 2003, the Kalispel Tribe annually electrofished four sloughs on their reservation (KNRD and WDFW 1998; Anderson 2000, 2002; Olson and Anderson 2004). Spring surveys were conducted in 1997 and 1998. Spring and fall surveys were conducted from 1999 to 2003. A total of 2,238 fish were collected between 1997 and 2003. None were bull trout. (See Olson and Anderson 2004 for a complete summary of this data set.)

In 2004, WDFW and the Kalispel Tribe conducted a survey of Box Canyon Reservoir using WDFW's warmwater fish survey protocol (Divens 2005). A total of 126 randomly selected electrofishing sites, 64 fyke net sites and 56 gill net sites were sampled between Box Canyon and Albeni Falls Dams over a four-day interval in May (Divens 2005). A total of 11,129 fish were collected in 20.6 hours of electrofishing, 2,964 by 64 net nights of fyke netting, and 1,432 by 56 net nights of gill netting (Divens 2005). The grand total was 15,525 fish sampled by all methods combined. No bull trout were collected.

In 2003, EWU and Battelle Pacific Northwest Laboratories sampled 505 fish, including six bull trout during 5.2 total hours (32 transects) of electrofishing in the tailrace area below Albeni Falls Dam (Geist et al. 2004). Relative abundance of bull trout in the sample was 1.2% and CPUE was 1.2 bull trout per hour. Four additional bull trout were collected in electrofishing surveys targeted to catch only bull trout. Nine of the ten fish were captured in a culvert on the left bank one km below the spillway and one was collected at Indian Creek 14 km below the Dam (Geist et al. 2004).

In the present survey, 2,113 fish, including two adult bull trout, were captured by 12.3 hours of electrofishing between Indian Creek and Albeni Falls Dam. Relative abundance of bull trout was 0.10 percent and CPUE was 0.2 bull trout per hour. The bull trout were captured at the culvert one km below the dam (left bank) and 0.5 km from the U.S.

Highway 2 bridge (right bank). Additionally, 92 fish, but no bull trout, were captured in the mouth of Indian Creek.

Collectively, these various surveys have examined 114,793 fish from Box Canyon Reservoir between 1987 and 2004. Of these, 19 were bull trout. The majority of bull trout (n = 12 of 19) were captured during surveys conducted in 2003 and 2004 that targeted the 14 km reach between Indian Creek and Albeni Falls Dam. Reservoir wide surveys or surveys conducted in the middle of the reservoir near the Kalispel Indian Reservation produced relatively poor CPUE for bull trout (0.0 – 0.02 bull trout per hour) whereas those that targeted the tailrace are produced relatively good CPUE for bull trout (0.2 – 1.2 bull trout per hour). These data suggested that bull trout are not uniformly distributed throughout the reservoir. Rather, they appeared to be concentrated in the tailrace area below Albeni Falls Dam.

Barber et al. (1989a, 1989b, 1990) reported on the results of reservoir wide creel surveys conducted in Box Canyon Reservoir in 1988 and 1989. The reservoir was stratified into three sections. Estimates of fishing pressure and CPUE (by species) were obtained by making pressure counts and conducting angler interviews on randomly selected dates and then expanding these numbers to account for dates not sampled. Estimates (± 95 percent confidence intervals) were provided for total fishing pressure, total catch and total harvest averaged over the entire reservoir. No bull trout were caught in an estimated catch of 10,082 ± 1181 fish (2,505 ± 312 harvested) with 4,139 ± 478 angler hours of effort expended in 1988 (Barber et al. 1989a, 1989b). However, 181 ± 23 bull trout were caught in an estimated catch of 18,171 ± 2,248 fish (1,331 ± 164 harvested) with 3,029 ± 374 angler hours of effort in 1989 (Barber et al. 1990). All of the bull trout were harvested.

After reviewing these data, we believe the bull trout estimate was too high because all of the bull trout were caught in the upper section of the reservoir between Indian Creek and Albeni Falls Dam. However, when the data were expanded, the species CPUE was multiplied by the reservoir wide angler pressure, causing an overestimate of their harvest. When we multiplied the bull trout CPUE by the section angler pressure the result showed a harvest of 40 ± 5 bull trout. In either case, Barber et al. (1990) and Ashe and Scholz

(1992) noted that harvest of bull trout in the Pend Oreille River was too high in relation to their low relative abundance and CPUE in concurrent electrofishing and gill net surveys, and recommended that their harvest be restricted. In 1992, the Washington Wildlife Commission implemented angling restrictions statewide, including prohibition of any recreational harvest in eastern Washington (Mongillo 1993).

Twenty of the 22 tributaries of the Pend Oreille River have been surveyed for presence or absence of bull trout (reviewed by Stovall et al. 2001; Andonaegui 2003; Shuhda 2004). Eastern Washington University (Barber et al. 1989a, 1989b, 1990; Ashe et al. 1991; Clark 1991) surveyed (by electrofishing) four sites in each of five tributaries over a three year period (1988-1990). The University of Idaho (Bennett and Liter 1991) surveyed (by electrofishing) one site in each of 13 tributaries in 1990. Plum Creek Timber Company surveyed 5-12 sites in eight tributaries in 1993-1994 (Watson et al. 1997; Pend Oreille County PUD 2000). The Untied States Forest Service surveyed six tributaries in 1995 (Pend Oreille County PUD 2000).

The Kalispel Tribe conducted three types of surveys between 1995 and 2003. Upstream/downstream migration traps were monitored near the mouths of six to 11 tributaries in each year from 1997-2000 to capture adfluvial fish migrating to or from the Pend Oreille River (Scott 1999; Lockwood et al. 2001). Twelve different tributaries were monitored over the course of this study: three for four years, five for three years, one for two years and four for one year. The Tribe also made structural improvements to habitat in six tributaries during 1995 and has monitored (by snorkeling) these reaches each year since (1995-2003) to determine if native fish abundance has increased (KNRD and WDFW 1996, 1997, 1998; Anderson 2000, 2001; Olson and Anderson 2004). Additionally, in 2001 the Tribe began systematically surveying a large number of randomly selected site throughout the length of each Box Canyon tributary: a total of 15 tributaries were surveyed in 2001, 2002 and 2003 (Conner et al. 2003a; 2003b; Olson and Anderson 2004).

Bull trout records for individual creeks, organized by point of entry into the Pend Oreille River (RKM), are summarized below:

- Cedar Creek (RKM 60.8 left bank) sampled by electrofishing by (Bennett and Liter 1991; KNRD and WDFW 1996). A combined total of seven sites were surveyed. One adult bull trout was captured near the mouth in 1995 (KNRD and WDFW 1996). A migration trap was monitored in 1998, 1999, and 2000: no bull trout were captured in a sample of 149 fish (Scott 1999; Lockwood et al. 2001). In 2003, a Kalispel Tribe biologist observed a 262 mm bull trout below the dam in Cedar Creek (Shuhda 2004).
- Big Muddy Creek (RKM 61.1, left bank). A migration trap was operated in 1998: but no bull trout were caught in a sample of 57 fish (Scott 1999; Lockwood et al. 2001)
- Renshaw Creek (RKM 67.6, left bank). No record of sampling
- Lost Creek (RKM 76.9, left bank). Both the main stem and South Fork were sampled by Bennett and Liter (1991) and USFS in 1995 (Pend Oreille County PUD 2000). USFS sampled 401 fish in the main stem and 55 fish in the South Fork. No bull trout were collected in either survey.
- Ruby Creek (RKM 83.7, left bank). Sampled by electrofishing from 1988-1990 by EWU (Barber et al. 1989a, 1989b, 1990; Ashe et al. 1991a; Clark 1991) in 1991 (by Bennett and Liter 1991) and in 1995 (by USFS, cited in Pend Oreille County PUD 2000). At least six sites were surveyed: 1,235 fish were caught (768 by EWU and 467 by USFS) but no bull trout. The USFS also sampled the North Fork of Ruby Creek: 21 fish were caught but no bull trout. A migration trap was operated in 1998, 1999 and 2000. No bull trout were caught in a sample of 142 fish (Scott 1999; Lockwood et al. 2001).
- LeClerc Creek (RKM 90.4, right bank) was sampled by electrofishing from 1988-1990 (by Barber et al. 1989a, 1989b, 1990; Ashe et al. 1991a; Clark 1991), in 1990 (by Bennett and Liter 1991), in 1993-1994 (by Plum Creek Timber Company – see Watson et al. 1997; Pend Oreille County PUD 2000). At least 10 sites were surveyed with 311 fish captured but no bull trout. A migration trap set near the mouth in 1997 captured six fish but no bull trout (Scott 1999). The East Fork and, West Branch and Middle Fork of LeClerc

Creek were surveyed by Plum Creek Timber in 1993-1994. Two juvenile bull trout were captured in a sample of seven fish from the East Fork, one juvenile bull trout was captured in a sample of 12 fish from the West Fork, and none were captured in a sample of 12 fish from the Middle Fork (Watson et al. 1997). In 1995, Kalispel Tribal biologists observed one adult bull trout in the East Fork (Shuhda 2004). The Kalispel Tribe Migration traps, placed in the East Fork and West Branch in 1998, 1999 and 2000 captured respectively 88 and 52 fish but no bull trout (Lockwood et al. 2001; Scott 1999). A female bull trout was observed by the Kalispel Tribe digging in redd in the West Branch in 2001 (Shuhda 2004). Tributaries of LeClerk Creek sampled following habitat enhancement included Fourth of July, Mineral and Whitman Creeks (KNRD and WDFW 1996, 1997, 1998; Anderson 2000, 2002; Olson and Anderson 2004). Each of these tributaries was sampled from 1996-2003. No bull trout were caught in Mineral or Whitman Creeks, but two (one each in 1998 and 1999) were caught in Fourth of July Creeks (Anderson 2000, 2002). A local informant told Shuhda (2004) that "*large numbers*" of 5-15 lb bull trout spawned at the mouth of LeClerk Creek during the early 1950's. We collected an adult bull trout during a boat electrofishing survey at the mouth of LeClerc Creek in September 1988. A second large adult bull trout was observed but not landed by the dipnet crew during the survey.

- Middle Creek (RKM 92.7; right bank). Sampled by electrofishing at one site in 1990 (Bennett and Liter 1991). No bull trout were collected. A migration trap set in 1998 collected no bull trout in a sample of 25 fish (Scott 1999, Lockwood et al. 2001).
- Mill Creek (RKM 93.8; right bank). Sampled by electrofishing at one site in 1990 (Bennett and Liter 1991) and two sites in 1995 (KNRD and WDFW 1996). No bull trout were collected during either survey but one was observed during a snorkel training event in 1995. The Tribe conducted additional surveys in 1996 and 1997 but discovered no additional bull trout (KNRD and WDFW 1997, 1998). In the latter survey they collected 340 other fish.

Migration traps at the mouth of Mill Creek in 1997 and 1998 collected 21 fish but no bull trout (Scott 1999; Lockwood et al. 2001).

- Loop Creek (RKM 95.1; right bank). No record of sampling.
- Cusick Creek (RKM 99.1; left bank). Surveyed by the Kalispel Tribe in 2002 (Conner et al. 2003a). No bull trout were collected in a sample of 1,180 fish.
- Tacoma Creek (RKM 102.5; left bank). Sampled by electrofishing at four locations annually from 1988-1990 by EWU (Barber et al. 1989a, 1989b, 1990; Ashe et al. 1991a; Clark 1991) and at one site in 1990 by UI (Bennett and Liter 1991). No bull trout were collected in a sample of 859 fish examined in the EWU surveys and none were collected in the UI study. No bull trout (but also no fish) were collected in a migration trap maintained by the Kalispel Tribe in 1997 (Scott 1999). In 1993 and 1994, Plum Creek Timber sampled 12 sites in the South Fork of Tacoma Creek and collected no bull trout (Watson et al. 1997; Pend Oreille County PUD 2000).
- Trimble Creek (RKM 106.6; left bank). Sampled in 2002 by the Kalispel Tribe (Conner et al. 2003b). No bull trout were collected in a sample of 138 fish.
- Cee Cee Ah Creek (RKM 106; right bank). Sampled by electrofishing at four locations annually from 1988-1990 by EWU. No bull trout were observed in a sample of 1,004 fish collected by electrofishing during these surveys (Barber et al. 1989a, 1989b, 1990; Ashe et al. 1991a, Clark 1991). None were captured in an electrofishing survey at one site in 1990 by Bennett and Liter (1991). None were captured at 12 sites by Plum Creek Timber 1993-1994 (Watson et al. 1997; Pend Oreille County PUD 2000). None were caught in various surveys by the Kalispel Tribe between 1995 and 2003 (KNRD and WDFW 1996, 1997, 1998; Anderson 2000, 2002; Olson and Anderson 2004). No bull trout were caught in a migration trap operated from 1997-2000 that sampled 159 fish over the interval (Scott 1999; Lockwood et al. 2001). A habitat site in Brown’s Creek, the principle tributary of Cee Cee Ah Creek, was sampled by

the Kalispel Tribe from 1996 to 2003 but no bull trout were observed (KNRD and WDFW 1997, 1998; Anderson 2000, 2002; Olson and Anderson 2004).

Two bull trout were caught in the slough that connects Cee Cee Ah Creek to the Pend Oreille River during boat electrofishing surveys, an adult in September 1989 (Barber et al. 1990) and a subadult in June 1990 (Ashe et al. 1991a).

- Calispel Creek (RKM 112.0, left bank). Three tributaries were surveyed: one site on the North Fork in 1990 by Bennett and Liter (1991), and Middle Fork (n = 8 sites) and Winchester Creek (n = 12 sites) in 1993 – 1994 by Plum Creek Timber (Watson et al. 1997; Pend Oreille County PUD 2000). No bull trout were collected in any of these surveys.
- Davis Creek (RKM 116.8, left bank). One site sampled in 1990 by Bennett and Liter (1991). Eight sites sampled on Davis Creek (n = 1,007) fish and two sites on Deer Creek (tributary of Davis Creek) (n = 224 fish) in 2001 by Conner et al. (2003b). No bull trout were collected during any of these surveys.
- Skookum Creek (RKM 117.8, right bank). No bull trout were observed in a sample of 1,049 fish collected in seasonal sampling at four sites annually from 1988-1990 (Barber 1989a, 1989b, 1990; Ashe et al. 1991a; Clark 1991). None were caught by Bennett and Liter (1991). None were caught during a survey of nine sites in selected tributaries in 2001 by Conner et al. (2003a). None were caught during four years of migration trap monitoring in the Skookum Creek main stem (n = 0 bull trout in 267 fish trapped) (Scott 1999; Lockwood et al. 2001). However, one adult bull trout was captured during a boat electrofishing survey in Red Norse Slough at the mouth of Skookum Creek in September 1989 (Barber et al. 1990).
- Brackett Creek (RKM 124.1; left bank). Surveyed in 2002 by Conner et al. (2003a). No bull trout were observed in a sample of 50 fish.

- Kent Creek (RKM 126.3; left bank). Three sites each in Kent and McCloud Creeks were surveyed in 2002 (Conner et al. 2003a). No bull trout were collected in samples from either Creek (n = 445 fish at Kent Creek and 217 fish at McCloud Creek).
- Indian Creek (RKM 130.7; right bank). No bull trout were sampled in Indian Creek (one site) by UI in 1990 (Bennett and Liter 1991), or during habitat improvement monitoring studies conducted by Kalispel Tribe from 1995-2003 (KNRD and WDFW 1996, 1997, 1998; Anderson 2000, 2002; Olson and Anderson 2004). Migration traps monitoring on Indian Creek was conducted annually from 1997-2000 (Scott 1999; Lockwood et al. 2001). One bull trout was present in a sample of 253 fish collected during this interval. The bull trout, a gravid adult female was collected in September 1999 in the downstream side of the trap. It bore a fin clip indicating that it had been released at Trestle Creek in Lake Pend Oreille. The fish was given a tag and released. It was caught in June 2002 by an angler near Marshall Creek, about four km upstream from Indian Creek. Bull trout have been collected by boat electrofishing at the mouth of Indian Creek. One adult in September 1987 by Barber et al. (1989a), one adult in July 2003 by Geist et al. (2004) and one large adult was observed in October 2004 (present study). From our cursory inspection of Indian Creek, there appeared to be relatively little pool habitat that would hold bull trout. Bull trout entering this stream may be attracted by the cold water refuge it provides rather than using it as a home spawning tributary.
- Marshall Creek (RKM 134.7; right bank). One site surveyed in 2001 by Conner et al. (2003a). No fish of any kind were collected.

In summary, the presence of bull trout has been confirmed in four tributary drainages of the Box Canyon Reservoir: Cedar, LeClerc, Mill and Indian Creeks. Additionally, bull trout were collected at the mouths of LeClerc, Cee Cee Ah, Skookum and Indian Creeks by boat electrofishing. Of these streams, LeClerc appeared to hold a remnant population of bull trout that is still naturally reproducing as evidenced by multiple captures of adults and juvenile in different tributaries (three in East Fork, two in West Branch, and two in Fourth of July Creek). Given the low encounter rates of bull trout in fish surveys, it may also now be difficult for spawning fish to locate each other, so it is uncertain how much longer this population will remain viable. Immediate corrective actions should be taken to preserve the remaining genetic variability of this population as it is probably the only significant population still left in the Box Canyon reach of the Pend Oreille River.

Bull trout were not detected in most tributaries, and only one or two individuals were detected in others. Failure to encounter bull trout in most tributaries does not necessarily confirm bull trout are absent in them, but does suggest that their populations are even lower than in LeClerc Creek. The failure of most migration traps to collect any migratory bull trout anywhere in the reservoir suggested that populations remaining in tributaries are most likely resident life history forms.

Albeni Falls Reservoir (includes Priest River, Pend Oreille River, and Lake Pend Oreille).

Albeni Falls Dam (approx. 19.8 m high at RKM 145.6), completed in 1955 by the U.S. Army Corps of Engineers is part of the Federal Columbia River Power System (FCRPS). Power produced at FCRPS dams is marketed by the Bonneville Power Administration (BPA). Albeni Falls has a unique feature found on no other hydroelectric dam in the Pacific Northwest – a log chute. In the heyday of the timber industry, Pend Oreille River was a major transportation corridor for rafting logs. The log chute was incorporated into the design of the dam to enable log transport.

In its Biological Opinion following the listing of bull trout as a threatened species, the USFWS (2000) noted:

"*Bull trout were abundant in the Pend Oreille River through 1957, and then abruptly their numbers decreased to the point that individual fish are now noteworthy. This abrupt decline correlates with the commencement of operation of Albeni Falls Dam in 1952. No other abrupt or widespread threat can be identified for this portion of the Pend Oreille River basin during the 1950's. In the absence of passage, migratory bull trout remaining in the Pend Oreille River will continue to be harmed.*"

Albeni Falls Reservoir inundated the upper 28.9 km of the Pend Oreille River, a 31.5 km segment of Lake Pend Oreille, and the lower 16.9 km of the Clark Fork River to the tailrace of Cabinet Gorge Dam (total reservoir length = 77.3 km). The Priest River, which enters the reservoir from the right bank at RKM 153.2, 8.1 km above Albeni Falls, is the closest major tributary to the Dam. The Priest River flows 69.5 km from outlet dam at the south end of Priest Lake to its confluence with the Pend Oreille River. Thirteen tributaries enter this stretch of Priest River, including East River on the left bank at RKM 33.5 (Priest River RKM). Outlet Dam is a fish migration barrier. Above the dam, Priest Lake, upper Priest Lake and their tributaries harbor isolated populations of adfluvial and resident bull trout. Below Outlet Dam, bull trout in the Middle Fork East River make adfluvial migrations to Lake Pend Oreille (Dupont and Horner 2004; Geist et al. 2004).

Lake Pend Oreille, the largest natural lake in Idaho, has a surface area of 38,362 hectares, mean depth of 30 m, and maximum depth of 351 m (Merriam 1975; PBTTAT 1998). It is classified as an oligotrophic lake. The perimeter of its shoreline is 282 km. Two major tributaries (Pack River and Trestle Creek) enter along the north shore of the Lake, two (Gold and Granite Creeks) enter along the east shore of the southern arm of the lake, and three (Johnson, Lightning and Twin Creeks) enter along the Clark Fork arm of the lake.

The first report of bull trout in Lake Pend Oreille was by George Suckley (1860): "*In Lake Pend d'Oreille…I have seen a very handsome species of red-spotted lake trout. The spots along the flanks are the size of large peas, and are of a beautiful rose color*." The length of adults averaged 20 inches.

Fish surveys in Lake Pend Oreille and Priest lake Basins, Idaho were conducted by: Bjornn (1957, 1961); Jeppson (1960); Klavano (1960); Mallet (1968); Anderson (1971); Goodnight and Mauser (1977, 1978, 1979, 1980, 1981); Bowler et al. (1978, 1979); Ellis and Bowler (1981); Mauser and Horner (1982, 1983); Rieman and Horner (1984); Horner and Rieman (1985); Pratt (1985); Horner et al. (1986, 1987, 1988, 1989); Mauser et al. (1988); Hoelscher and Bjornn (1989); Maiolie et al. (1991); Bennett and Dupont (1993); Pratt and Huston (1993); Paragamian and Ellis (1994); Davis and Horner (1995); Saffel and Scarnecchia (1995); Davis et al. (1996, 1997, 2000); Nelson et al. (1996, 1997);

Rieman and McIntyre (1996); Fredericks et al. (1997, 2000, 2001, 2002); Rieman and Myers (1997); Vidergar (2000); Downs et al. (2003).

Two fish surveys have been conducted in the segment of the Pend Oreille River between Albeni Falls Dam and its source at the outlet of Lake Pend Oreille. The first was made by IDFG in 1986 (Horner et al. 1987). Seven gill nets (four sinking, three floating) set overnight on August 27-28 captured 529 fish but no bull trout (Horner et al. 1987). The second survey was made in 1991 and 1992 by the University of Idaho (UI) (Bennett and Dupont 1993). A total of 23 species and 45,475 fish (25,688 in 1991 and 19,787 in 1992) were collected, including five bull trout (three in 1991 and two in 1992), in 23.7 hours of electrofishing and 15,743 hours of gillnet sets (Bennett and Dupont 1993).

In the Priest River drainage, bull trout were once common above the outlet Dam on the lower Priest Lake. Bull trout populations in many tributaries made adfluvial migrations into Priest and Upper Priest Lake (Bjorn 1957). As recently as 1978, sport harvest of bull trout in Priest Lake was estimated at 2,300 fish and overharvest was identified as a factor contributing to their decline (Mauser et al. 1988; Stovall et al. 2001). Competition with introduced lake trout and habitat loss in tributary streams are also thought to impact this population. Electofishing surveys conducted by IDFG in eleven Priest Lake tributaries in 1984 captured 6,529 bull trout; bull trout were absent in three tributaries. A resurvey of the same tributaries in 1998 captured 69 bull trout; bull trout were absent in five tributaries (Fredericks et al. 2002).

Bull trout redd counts were made by IDFG in 12 tributaries of upper Priest Lake (Table A6). The eight year (1992-1999) average count was 30 redds (range 12-58 redds) per year (Fredericks et al. 2002), with comparatively more redds surveyed in later years (Table A6). The increase redd count was thought to be related to closure of the bull trout sportfishing in Priest and upper Priest Lake in 1984, which has resulted in increased spawning escapement. In 1999, spawning escapement of adfluvial bull trout into tributaries of upper Priest Lake was estimated between 128-191 individuals with about 91% of them spawning in the Priest River (Fredericks et al. 2002).

In 2002 and 2003, bull trout were captured in several tributaries of Priest Lake and Upper Priest Lake by the Kalispel Tribe for genetic samples (Maroney et al. 2003; Olson et al. 2004). Streams from which bull trout samples were collected in 2002 included: Upper Priest Lake (n = 39), Upper Priest River (n = 3), Bench Creek (n = 3), Hughes Fork (n = 3), Lime Creek (n = 16), Malcolm Creek (n = 13), Rock Creek (n = 7), Ruby Creek (n = 4), and Trapper Creek (n = 29). Streams from which bull trout samples were obtained in 2003 included: Upper Priest River (n = 50), Gold Creek (n = 50), Indian Creek (n = 20), Granite Creek (n = 1), North Fork Granite Creek (n = 6) and Hughes Fork (n = 3) (Olson et al. 2004).

Table A6. Number of bull trout redds counted in 12 tributaries of Priest and Upper Priest Lakes, Idaho. (Data from Fredericks et al. 2001, 2002) -- = not surveyed that year. [1]

Location	Number of bull trout redds counted in:											
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Priest River	--	5	5	3	25	8	35	53	18	22	21	37
Rock Creek	0	0	--	--	2	1	0	--	0	0	0	--
Lime Creek	0	0	--	--	0	2	0	1	0	0	0	0
Cedar Creek	--	0	2	1	0	1	0	0	0	0	0	0
Ruby Creek	0	0	--	--	--	0	0	--	--	--	0	--
Hughes Creek	9	4	9	1	5	7	1	1	2	6	1	2
Bench Creek	0	2	2	0	1	0	0	0	0	0	0	0
Jackson Creek	4	0	0	0	0	0	0	--	--	--	0	0
Gold Creek	5	2	6	5	3	0	1	1	9	5	2	2
Boulder Creek	0	0	0	--	0	0	0	--	0	--	--	--
Trapper Creek	--	4	4	2	5	3	8	2	0	1	0	0
Caribou Creek	--	1	0	0	0	0	0	--	--	--	--	--
Totals	**18**	**18**	**28**	**12**	**41**	**22**	**45**	**58**	29	34	24	41

[1] Number of tributaries surveyed varied each year: 1992 (n = 8), 1993 (n = 12), 1994 (n = 9), 1995 (n = 8), 1996 (n = 11), 1997 (n = 12), 1998 (n = 12), 1999 (n = 8), 2000 (n = 9), 2001 (n = 8), 2002 (n = 10) and 2003 (n = 8). No information presented in reports that discussed level of effort in relation to environmental factors.

Below the outlet dam on lower Priest Lake, bull trout occur in the main stem and two tributaries (Tarlac and Uleda Creeks) of the Middle Fork East River but not in the North Fork East River (Horner et al. 1987; Pratt and Huston 1993). Bull trout were also recorded in Big Creek but not in the North or Happy Forks of Big Creek (Horner et al.

1987). No bull trout were collected in Binarch Creek or the Upper West Branch of the Priest River (Horner et al. 1987).

Bull trout genetics were collected in Middle Fork East River (n = 40 in 2002, n = 70 in 2003) and Uleda Creek (n = 10 in 2002) (Maroney et al. 2003; Olson et al. 2004). Bull trout redd counts in Tarlac and Uleda Creeks numbered 7 in 2001 and 12 in 2002. In 2003, a spawner survey in the Middle Fork East River drainage counted 24 redds in the Middle Fork, Tarlac and Uleda Creeks and estimated spawning escapement as ranging between 53 and 77 fish (Dupont and Horner 2004). In 2003, 131 juvenile bull trout were collected in the Middle Fork East River, Tarlac and Uleda Creeks, of which 130 were marked with PIT tags (Geist et al. 2004).

Lake Pend Oreille was historically the most important sport fishery in Idaho. Between 1951 and 1958 and average of 2,924 bull trout, 949, 470 kokanee, 5,747 cutthroat trout, 2,619 cutthroat trout, 5,005 whitefish, 36, 514 yellow perch, 7,724 black crappie and 398 largemouth bass were harvested from its annually waters (Klavano 1960). Bull trout harvest from Lake Pend Oreille is recorded in Table A7.

Table A7. Record of Bull trout harvested in Lake Pend Oreille, Idaho 1951-1991 (Data from Klavano 1960, Mallett 1968, and Ellis and Bowler 1981, Bowler et al. 1978, 1979; Pratt and Huston 1993).

Year	***Estimated harvest***	***Year***	***Estimated harvest***	***Year***	***Estimated harvest***	***Year***	***Estimated harvest***
1951	1,775	1959	1,677	1967	657	1975	838
1952	2,359	1960	2,616	1968	624	1976	1,253
1953	5,035	1961	966	1969	862	1977	1,251
1954	3,660	1962	1,434	1970	640	1978	1,469
1955	3,811	1963	1,049	1971	967	1979	1,218
1956	3,288	1964	929	1972	928	1980	1,729
1957	2,117	1965	1,460	1973	751	1985	621
1958	1,348	1966	1,199	1974	847	1991	1,700

The abrupt decline in harvest after the middle 1950's was attributed to construction of Cabinet Gorge Dam in 1952, which blocked adfluvial bull trout maturing in the lake from their home spawning streams in the Clark Fork above the dam. Klavano (1960) summed up this argument by pointing out that in 1949 and 1950, the Montana Department of Fish, Wildlife, and Parks took 601,500 and 162,000 eggs from adult bull trout spawners returning to tributaries above the Cabinet Gorge dam site but "*these runs no longer exist*."

Assuming that some bull trout spawning in tributaries of Lake Pend Oreille dropped down through the lake into the Pend Oreille River during either their juvenile outmigration or adult post-spawning outmigration, closure of Albeni Falls Dam during this same time period may have similarly contributed to the decline of the population available for harvest in the lake. In addition to fragmentation of their habitat by dams, habitat alteration in spawning tributaries and competition with non-indigenous species such as lake trout and kamloops trout have contributed to their decline in Lake Pend Oreille (Stovall et al. 2001).

By about 1990, bull trout abundance had declined to such low levels that over harvest by anglers began to contribute to these problems. For example, in 1991 bull trout spawning escapement into tributaries of Lake Pend Oreille was estimated as ranging between 931-1,354 individuals (based on a red count 423). During that same year anglers in Lake Pend Oreille harvested (± 95 % CI) about 1,700 (± 900) bull trout (Pratt and Huston 1993). Thus, the total bull trout spawning population (harvest plus escapement) ranged from about 1,731 to 3,954 individuals and anglers harvested 37.1 to 65.8 percent of the spawning population. Additionally, although IDFG had closed bull trout harvest in tributaries to protect spawning populations, Pratt (1985) determined that total annual mortality of bull trout ages 4 – 6, ranged between 47 – 82 percent, of which illegal harvest in spawning tributaries was a major part. IDFG closed bull trout harvest in Lake Pend Oreille in 1996, due to pending listing as an ESA Threatened Species by the USFWS and declining spawning runs into tributaries.

Tributaries of Lake Pend Oreille were surveyed for presence or absence of bull trout (Anderson 1971; Pratt 1985; Hoelscher and Bjornn 1989; Pratt and Huston 1993; Downs et al. 2003). In tributaries along the east shore (south arm) bull trout were present in Gold, Granite and North Creeks and absent in Cedar, Falls and West Gold Creeks. In tributaries along the north store (near Sandpoint, Idaho), bull trout were present throughout Trestle Creek and in selected areas of the Pack River but absent in Sand Creek. In the Pack River drainage, bull trout were present in Grouse and Hellroaring Creeks and not detected in Berry, Caribou, Colburn, Gold, Jeru, McCormick, Rapid Lightning, Sand, Trout and Youngs Creeks.

In tributaries along the Clark Fork Arm of Lake Pend Oreille, bull trout were present in the main stem of the Clark Fork River below Cabinet Gorge Dam, and in Johnson, Lightning, and Twin Creeks, but absent in Mosquito Creek and certain tributaries of Lightning Creek. In the Lightning Creek drainage bull trout were present in the main stem from the mouth upstream to Quartz Creek, in its East Fork (including Char and Savage Creeks), and in Porcupine, Rattle, Spring, and Wellington Creeks. Bull trout were absent in the Lightning Creek main stem above a barrier falls located just below the junction of Quartz Creek. They were also absent in Cascade, Morris, and Quartz Creeks. Bull trout redds were observed in Morris Creek after 1999 and their presence was attributed to colonization of the creek by bull trout that had strayed from the East Fork of Lightning Creek (Fredericks et al. 2001).

Annual bull trout redd counts have been made in each of the tributaries of Lake Pend Oreille known to produce bull trout since 1983. These counts were summarized on Table A8. Estimates of the minimum and maximum spawning escapement were also shown. Both calculations assumed that all redds had been counted. The minimum estimate was made by multiplying the red count by 2.2 spawners per redd, the maximum estimate was made by multiplying the redd count by 3.2 spawners per redd. Total redd counts for the entire Lake Pend Oreille System were variable but evidenced a downward trend from 1983 to 1994 (Rieman and Myers 1997). The Lightning Creek drainage in particular exhibited a large decline in bull trout redds as shown in Table A9, which sums the total number of bull trout redds observed in the drainage and provides the percentage represented by that total of all bull trout redds in the Pend Oreille system.

From 1983 to 1995 the number of bull trout redds was variable from year to year but the trend showed an unmistakable decline. At one time, Lightning Creek drainage accounted for 37 percent of all the bull trout spawning in Lake Pend Oreille. In 1995 it accounted for five percent. Habitat degradation was a factor in the decline of bull trout in Lightning Creek after 1983. The Lightning Creek watershed receives about twice as much annual precipitation (81 inches) as other watersheds in the Pend Oreille Basin, making it more susceptible to mass wasting after it was logged. Numbers of redds in Lightning Creek and other tributaries increased after 1996, which was probably attributable to prohibition of harvest after 1996. Even so, the number of redds in individual tributaries of Lightning Creek was still relatively low, ranging from 1-77 (mean 21) in eight tributaries in 2004.

Declining numbers of spawning adults in tributaries with low redd counts was of concern because "*bull trout exhibit strong fidelity to natal streams,* [so] *some reproductive isolation is expected among streams and is evident from the genetic analysis* [of Spruell et al. 1999]" (Rieman and Myers 1997). Thus, further declines in already depressed population will likely result in the demise of these stocks.

Table A8. Number of bull trout redds counted in ten tributaries of Lake Pend Oreille, Idaho. (Data from Fredericks et al. 2001, 2002; Downs et al. 2003) -- = not surveyed that year. * denotes index streams.

Location	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Clark Fork River	--	--	--	--	--	--	--	--	--	2	8	17	18	3	7	8	5	5	6	7	8	1
Lightning Creek	28	9	46	14	4	--	--	--	--	11	2	5	0	6	0	3	16	4	7	8	8	9
*East Fork**	110	24	132	8	59	79	100	29	--	32	27	28	3	49	22	64	44	54	36	58	38	77
Savage Creek	36	12	29	--	0	--	--	--	--	1	6	6	0	0	0	0	4	2	4	15	7	15
Char Creek	18	9	11	0	2	--	--	--	--	9	37	13	2	14	1	16	17	11	2	8	7	14
Porcupine Creek	37	52	32	1	9	--	--	--	--	4	6	1	2	0	0	0	4	4	0	0	5	10
Wellington Creek	21	18	15	7	2	--	--	--	--	9	4	9	1	5	2	1	22	8	7	7	8	7
Rattle Creek	51	32	21	10	35	--	--	--	--	10	8	0	1	10	2	15	13	12	67	33	37	34
Morris Creek	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	0	7	1	1
Johnson Creek*	12	33	23	36	10	4	17	33	25	16	23	3	4	5	27	17	31	4	34	31	0	32
Twin Creek	7	25	5	28	0	--	--	--	--	3	4	0	5	16	6	10	19	10	1	8	3	6
North Shore																						
Trestle Creek*	298	272	298	147	230	236	217	274	220	134	304	276	140	273	221	330	260	301	335	333	361	102
Pack River	34	37	49	25	14	--	--	--	--	65	21	22	0	6	4	17	0	8	28	22	24	24
Grouse Creek*	2	108	55	13	56	24	50	48	33	17	23	18	0	50	8	44	50	77	18	42	45	45
East Shore																						
Granite Creek	3	81	37	37	30	--	--	--	--	0	7	11	9	47	90	49	41	25	7	57	101	149
Sullivan Springs Creek*	9	8	14	--	6	--	--	--	--	0	24	31	9	15	42	10	22	19	8	15	12	14
North Gold Creek*	16	37	52	8	36	24	37	35	41	41	32	27	31	39	19	22	16	19	16	24	21	56
Gold Creek*	131	124	11	78	62	111	122	84	104	93	120	164	95	100	76	120	147	168	127	203	126	167
Total	814	881	830	412	555	478	543	503	423	447	656	631	320	608	527	726	712	732	703	878	812	873
Min. spawn escapement	1,791	1,938	1,826	906	1,221	1,052	1,195	1,067	931	983	1,443	1,388	704	1,338	1,159	1,597	1,566	1,610	1,547	1,932	1,786	1,921
Max. spawn escapement	2,605	2,819	2,656	1,318	1,776	1,530	1,738	1,610	1,354	1,430	2,099	2,019	1,024	1,946	1,686	2,323	2,278	2,342	2,250	2,810	2,590	2,793

Notes:
1. Incomplete counts on Porcupine and Grouse Creeks in 1983; on Grouse, Rattle and East Fork Lightning Creeks in 1986; and on Granite Creek in 1987
2. In 1991, represents partial counts due to early snowfall (East Fork Lightning Creek index count not made).
3. In 1995, observation conditions impaired by high runoff except for Sullivan Springs, North Gold and South Gold Creeks and the Clark Fork River.
4. In 2000, a barrier prevented access to most spawning areas in Johnson Creek.
5. In 2001-2004, Trestle Creek count included redds counted in a 0.5 km area above the index site (n = 4 in 2001, n = 4 in 2002, n = 2 in 2003 and n = 5 in 2004.

Table A9. Total bull trout redd counts in Lightning Creek drainage in relation to redd counts all Lake Pend Oreille tributaries. Percent = percentage of lake population that spawned in Lightning Creek. – indicates not sampled that year.

Year	# bull trout redds in:		Percent
	Lightning Creek	**All tributaries**	
1983	301	814	37
1984	156	881	18
1985	286	830	34
1986	41	412	10
1987	152	555	27
1988	79	478	17
1989	100	543	18
1990	29	503	6
1991	--	423	--
1992	76	447	17
1993	92	656	14
1994	62	631	10
1995	9	320	3
1996	84	608	14
1997	27	527	5
1998	99	726	14
1999	121	712	17
2000	96	732	13
2001	123	703	17
2002	136	878	15
2003	111	812	14
2004	167	873	19

In 2001, 102 adult bull trout and 67 redds were counted respectively during snorkeling and spawning surveys in Rattle Creek, a tributary of Lightning Creek (Downs et al. 2003). The number of redds were 4 – 67 times higher than redd counts during the previous ten years and it was surmised that "*a substantial number of these fish were strays from other tributaries unable to access their natal streams due to low stream flows*," which resulted in intermittent segments in the Lightning Creek drainage (Downs et al. 2003). Genetic samples were taken from some of these fish because it might provide new information about the metapopulation structure of bull trout in the Lightning Creek drainage. Results of the genetic testing are not yet available.

In 2002, mark/recapture population estimates were made of the adult spawning populations in East Fork Lightning Creek, Grouse Creek, Gold Creek and Trestle Creek

(Downs et al. 2003). In these studies the number of fish examined (n) and estimated population (N) in each creek was: East Fork Lightning (n = 41, N = 75), Grouse (n = 161, N = 224), Gold (n = 136, N = 313) and Trestle Creek (n = 515, N = 1,114). Of these, one bull trout in Grouse Creek and one in Gold Creek bore adipose clips indicating that they had strayed from either Trestle or East Fork Lightning Creeks, where they had been marked in 1998, indicating that straying bull trout accounted for 0.9 – 2.8 percent of the populations in these streams (Downs et al. 2003). Additionally, eight Lake Pend Oreille tributaries were surveyed in 2001: Rattle Creek (n = 102 bull trout observed), Morris Creek (n = 1), Porcupine Creek (n = 0), Lightning Creek (n = 6), Wellington Creek (n = 14), North Gold Creek (n = 17), Granite Creek (n = 2), and Sullivan Springs Creek (n = 2). No adipose clipped bull trout were observed from either the 1998 or 2000 marking events among these bull trout, which suggested that "*although straying occurs, it may be infrequent or occurs at low levels*" (Downs et al. 2003).

Electrofishing surveys were made along a 4.7 km reach of the Clark Fork River below Cabinet Gorge Dam (RKM 234.1 – 238.9) in Fall 1999 (2 – 9 November), Spring 2000 (28 March – April 10), Fall 2000 (24 October – 2 November) and Fall 2001 (22 October – 1 November) (Downs et al. 2003). During the two fall surveys, a total of 1,590 fish, representing 13 species and including one bull trout were captured with 4.7 hours of electrofishing effort on the final night of sampling. Two bull (485 – 720 mm total length) trout were captured in 13.65 hours of electrofishing effort expended during the fall surveys (Downs et al. 2003). Mature adfluvial bull trout are also captured at the base of Cabinet Gorge Dam.

Cabinet Gorge Reservoir

Cabinet Gorge Dam (approx. 48.7 m high at RKM 241.2) was completed in 1952 by the Washington Water Power Company (now Avista Utilities). Its reservoir inundated 32.2 km of the Clark Fork River to the tailrace of Noxon Rapids Dam. Eight tributaries enter this reach, including the Bull River (RKM 261.5; right bank) and Rock Creek (RKM 271.4; right bank). Adfluvial bull trout from Lake Pend Oreille were able to migrate to the headwaters of the Clark Fork River and into many of its tributaries (Evermann 1892). Evermann (1892) stated that "*so far as we were able to determine, there are no natural* *obstructions anywhere above Lake Pend Oreille in this system – the Clark Fork of the Columbia River and its tributaries – which interfere seriously with the free movement of fishes. There are certainly no falls in the larger streams, and we know of none of any importance in the smaller ones.*" Spawning escapement of bull trout that formerly migrated from Lake Pend Oreille to tributaries of the Clark Fork River above Cabinet Gorge was estimated at 100,000 fish (USFWS 2000). Commencing in 1951, Cabinet Gorge Dam blocked adfluvial bull trout that matured in Lake Pend Oreille from returning to their natal tributaries above the dam. Pursuant to relicensing of Cabinet Gorge and Noxon Rapids Dams by the Federal Energy Regulatory Commission (FERC), a settlement agreement was developed between Avista and federal, state, local, and tribal governments that included provisions for restoring fish passage at each facility (Stovall et al. 2001).

Information about bull trout in Cabinet Gorge reservoir and tributaries entering the reservoir was summarized by Brunson (1952), Gaffney 1955, Huston (1985), Pratt and Huston (1993) and MBTSG (1995b). For the first few years following improvements, angler catches in Cabinet Gorge Reservoir were comprised of up to 50 percent bull trout, with catch rates up to 0.2 bull trout per hour (Gaffney 1955). Gradually, bull trout were prevented from reaching their natal spawning tributaries and their population declined, which was reflected in reduced rate of harvest in angler creels. Creel and gillnet surveys conducted in Cabinet Gorge Reservoir from 1954-1958 also showed that bull trout were the most abundant salmonid despite the stocking of approximately 1.7 million kokanee fry, 1.2 million Yellowstone cutthroat trout fingerlings and 100,000 coho salmon fry into the reservoir (Huston 1985). In surveys conducted in 1960, 1969, 1982 and 1983 bull trout catch declined (to 0.8, 0.3, 0.0 and 0.6 fish per net night). Brunson (1952) and Gaffney (1955) collected mature adfluvial (1.6-8.8 lb) bull trout in migration traps and gill nets respectively in the mouth of the Bull River. Gaffney (1955) also gill netted bull trout at the mouth of Elk Creek.

Historically, bull trout were present in Elk Creek main stem and its East Fork; Bull River main stem from the mouth to its confluence with its South Fork, and also Cooper Gulch Creek and the East Fork of the Bull River; Pilgrim Creek; Government Creek; and Rock

Creek and its East Fork (Pratt and Huston 1993). Bull trout were absent in Blue Creek; Deadhorse Creek; Eddy Creek; Black Tail Creek; Basin Creek and South, Middle, and North Forks of the Bull River (Pratt and Huston 1993). By 1993, bull trout had been extirpated from two tributaries that they had historically occupied (East Fork Elk and Government Creeks) and their status was uncertain in two others (Elk Creek main stem and Pilgrim Creek) (Pratt and Huston 1993).

Noxon Rapids Reservoir

Noxon Rapids Dam (approx. 79.3 m high at RKM 273.1) was completed in 1960 by the Washington Water Power Company (now Avista Utilities). Its Reservoir inundated 61.1 km of the Clark Fork River. Fourteen tributaries enter the Clark Fork between Noxon Rapids and Thompson Falls dams. The largest is the Vermillion River, which adds the water of 20 affluents along its 34.9 km length, and enters from the right bank at RKM 299.1.

Prior to closure of Noxon Rapids Dam in August 1958, the Clark Fork River between the head of Thompson Falls Reservoir and the upper end of Cabinet Gorge Reservoir was treated with rotenone. Bull trout abundance in gill net sets declined from 1.3 bull trout per net set in 1960, to 0.3 (in 1969), to 0.3 (in 1982) to 0.1 (in 1983) (Huston 1985).

Information about bull trout in Noxon Rapids Reservoir and tributaries entering the reservoir was summarized by Brunson (1952), Gaffney (1955), Huston (1985), Pratt and Huston (1993) and MBTSG (1996b). Brunson (1952) trapped bull trout in a trap set at the mouth of Prospect Creek. Gaffney (1955) collected mature adult bull trout in gill nets at the mouths of Beaver and Martin Creeks, and observed large bull trout in the Vermillion River, Prospect Creek and Martin Creek.

Historically, bull trout were present in Stevens Creek, Swamp Creek and its tributary (Galena Creek); Marten Creek and its South Fork; Tuscor Creek; Vermillion River to a barrier falls at the head of China Gorge and its tributaries (Canyon Creek); Graves Creek to a barrier falls; Mosquito Creek; Lower Prospect Creek and several of its tributaries. Tributaries of Prospect Creek supporting bull trout populations included Wilkes Creek, Clear Creek, Therrault Creek, and Crow Creek (Pratt and Huston 1993). Bull trout were absent in McKay Creek; Vermillion Creek upstream of a barrier falls, several tributaries of the Vermillion River (Sims Creek, Lyons Creek, Cataract Creek and Grouse Creek); Beaver Creek and its tributaries; Graves Creek above the barrier falls, Squaw Creek and upper Prospect Creek and several of its tributaries (Dry Creek, Shorty Gulch, Copper Creek, Cooper Creek, Evans Creek, 24-mile Creek) (Pratt and Huston 1993).

By 1993 bull trout had been extirpated from three tributaries that they historically occupied (Galena Creek – tributary of Swamp Creek, and Wilkes and Cow Creeks – tributaries of Prospect Creek) and their status was uncertain in five others (South Fork Marten Creek, Tuscor Creek, Canyon Creek – tributary of Vermillion River, Mosquito Creek, Clear Creek – tributary of Prospect Creek) (Pratt and Huston 1993).

Thompson Falls Reservoir and Middle Clark Fork River (includes Flathead and Bitterroot Rivers)

Thompson Falls Dam (approx. 16.5 m high at RKM 334.7) was completed in 1952 by the Montana Power Company. Its reservoir inundated 19.3 km of the Clark Fork River. Milltown Dam is located 193 km above Thompson Falls Dam. This reach is often called the Middle Clark Fork River. Sixty-six tributaries enter the Clark Fork between Thompson Falls and Milltown Dams. The most important are: Thompson River (enters from right bank at RKM 345.3), Flathead River (RKM 394.2, right bank), St. Regis River (RKM 435.6, left bank) and Bitterroot River (RKM 564.0, left bank). Bull trout in the Middle Clark Fork River and its tributaries made adfluvial migrations to Lake Pend Oreille (MBTSG 1996c). Tributaries also probably had resident populations as well as fluvial populations that migrated to and matured in the Middle Clark Fork main stem.

The Thompson River flows 70.0 km from the outlet of Thompson Lake to its confluence with the Clark Fork. It is joined by 22 affluents over its course. The West Fork Thompson River is a notable bull trout stream (MBTSG 1996c).

The Flathead is a large complex system with Flathead Lake at the center. Below the outlet of Flathead Lake, the river winds 123.1 km to the mouth. In this segment the Flathead is joined by 21 tributaries, including the Jocko River (RKM 40.9, left bank), Mission Creek (RKM 51.7, left bank) and Little Bitterroot River (RKM 72.4, right bank).

Kerr Dam (70 m high at RKM 115.8), just below the outlet of Flathead Lake is a fish migration barrier. The lower Flathead River flows through the Flathead Indian Reservation, home of the Confederated Salish and Kootenai Tribes (CSKT). It is probable that bull trout from Flathead Lake may have migrated downstream into the Flathead River (MBTSG 1996c).

Flathead Lake extends 42.6 km between the outlet and inlet (RKM 165.7). Flathead Lake has a surface area of 495.9 sq. km, average depth of 50.2 m, maximum depth of 113.0 m and shoreline perimeter of 301.9 km including the islands and 259.7 km without the islands. Eighteen tributaries drain into the Lake. Only the Swan River, which enters on the northeast corner of the lake, is a major tributary. The Swan River is 113.4 km in length and is joined by 53 named tributaries. Big Fork Dam is located at RKM 2.4 and is a migration barrier on the Swan River. Swan Lake is an enlargement of the Swan River between (RKM 23.2 – 36.8). Adfluvial bull trout from many tributaries in the Swan River drainage mature in Swan Lake.

Above the inlet of Flathead Lake, the Flathead River extends 256.6 km to its headwaters in Canada (Flathead RKM 424.5). Above RKM 260.8 it is called the North Fork Flathead River. In the segment between the lake outlet and where it becomes the North Fork, the river is joined by eight tributaries. Major tributaries include the 64.7 km long Stillwater River (RKM 201.7, right bank, three tributaries), 168.3 km long South Fork (RKM 239.3, left bank, 45 tributaries), and 146.6 km long Middle Fork (RKM 254.7, left bank, 56 tributaries). Hungry Horse Dam (164.4 m high at RKM 8.4 of South Fork) blocked migratory bull trout that historically migrated between Flathead Lake and the South Fork.

The St. Regis River flows 56.0 km from its headwaters to its confluence with the Clark Fork. Twenty tributaries join the St. Regis.

The Bitterroot River flows 129.0 km between the junction of its East and West Forks and the Clark Fork. Over this distance it is joined by 39 tributaries (12 on the east side, 27 on the west side). The East Fork is 58.6 km long and joined by 33 tributaries. The West Fork is 31.9 km long below West Fork Dam (Painted Rocks Reservoir) and joined by ten tributaries.

Little information was located regarding bull trout in Thompson Falls Reservoir or the Clark Fork between the of the reservoir and Milltown Dam. Only remnant population of bull trout appear to be present in the Clark Fork or any of its minor tributaries between Thompson Falls and Missoula (Cooper 1869; Huston 1961; Berg 1986, 1989, 1992; MBTSG 1996c). Decades of mining and pulp mill pollution contributed to their demise in this area.

Cooper (1869) collected a bull trout at the mouth of the St. Regis River (his St. Regis Borgia Creek). Evermann (1892, 1893) reported that bull trout were present in the Clark Fork River above and below Missoula, Montana, Flathead River above and below Flathead Lake, Flathead Lake, Swan Lake, Jocko River, Bitterroot River and "abundant" in Rattlesnake Creek (near Missoula).

Electrofishing surveys were conducted in six reaches of the Clark Fork River between the mouth of the Flathead River and Milltown Dam from 1983 to 1993 by MDFWP (MBTSG 1996c). Sampling occurred on 240 days (1147 hours of electrofishing effort) during this 11 year period. A total of 28,896 salmonids were captured during these surveys, including 127 bull trout ranging from 178-780 mm (MBTSG 1996c). Bull trout relative abundance was 0.44 percent of salmonids sampled and CPUE was 0.09 fish per electrofishing hour (MBTSG 1996c).

Fish surveys conducted by MDFWP between 1953 and 1970 recorded the presence of bull trout in the following Middle Clark Fork tributaries: Cedar Creek, Dry Creek, Fish Creek, Little Joe Creek, Little Joe Creek (South Fork), Ninemile Creek, Rattlesnake Creek, St. Regis River, Spring Gulch Creek, Trout Creek, Twelvemile Creek, and Ward Creek (MBTSG 1996c).

Bull trout still occur in many of these tributaries (Berg 1986, 1989, 1992; MBTSG 1996c). The most important tributaries used for spawning by migratory bull trout include Cedar, Fish, Fishtrap, and Petty Creeks and the St. Regis River. Bull trout spawners and redds were observed in the main stem, North and West Forks of Fish Creek (MTBSG 1996c). The Montana Water Company Dam on Rattlesnake Creek blocked bull trout migration to the headwaters. Mature adfluvial bull trout from the Clark Fork congregated annually at the base of the dam but it was unknown if they spawned successfully below the Dam (MTBSG 1996c). A resident population of bull trout reproduces successfully above the Dam (MBTSG 1996c). Resident populations also occur in Cedar, Dry, Fish, Grant, Ninemile, Petty, Tamarack and Trout Creeks (Berg 1986, 1992). Dry, Grant, Ninemile and Tamarack Creeks probably formerly supported migratory forms but their connections with the Clark Fork are now dry for much of the year, owing to irrigation diversions and commercial development (MBTSG 1996c).

Lieutenant John Mullan, United States Army, visited Flathead Lake in April 1854 as part of the Pacific Railroad Survey exploring expeditions lead by the first territorial governor of "Washington Territory," I.I. Stevens. On April 20, 1854, "*Just below the outlet of* [Flathead] *Lake there is a series of rapids and falls* [that extended downriver for eight miles] *one of which … was 15 feet high*,"…(Stevens 1860). Four lodges of Indians were camped on the lake near the outlet and had been their fishing for several weeks. "*They presented us, on arriving at their camp, with some fresh and dried salmon-trout* [i.e., bull trout]. *This lake* [Flathead Lake], *and also the Clark's Fork* [i.e. Lower Flathead River] *here, abounds in excellent fish, the salmon-trout being the most abundant. The latter are caught from the lake, often measuring three feet long*," (Mullan 1854). Stevens (1860) further noted that salmon-trout supplied "*one of the principle articles of subsistence to the Indians of the country*."

Although the 15 ft falls described by Mullan and Stevens sounds like an imposing migration barrier, the braided network of channels in the rapids region apparently provided alternative migration pathways to fish trying to surmount them. Examinations made at Flathead Lake by Barton Evermann and his coworkers in 1891 and 1892 found these "falls" to "*consist simply of a series of rapids, which do not interfere in the least with the free movement of fish*" (Gilbert and Evermann 1895). Evermann (1893) also noted that salmon-trout [bull trout] were common in Flathead Lake and "*caught in certain seasons in considerable numbers*."

Bull trout are abundant in the Flathead drainage. Fish surveys in Flathead Basin include: Schultz (1941); Block (1955); Stefanich (1958); Gaffney (1959); Kinnie (1960); Flathead National Forest (1948); Morton (1968); Graham et al. (1980); Fraley et al. (1981); Pratt (1984); Shepard et al. (1984); Leathe and Enk (1985); Cross and Dos Santos (1988); Dos Santos et al. (1988); May et al. (1988); Fraley and Shepard (1989); Spencer et al. (1991); Thomas (1992); Weaver (1992); Hansen and DosSantos (1993a, 1993b); Rieman and McIntyre (1993, 1995, 1996); Kitano et al. (1994); MBTSG (1995d, 1995e, 1996a, 1996c); Rieman and Myers (1997) and Muhfeld et al. (2003).

Electrofishing surveys conducted between 1983 and 1986 by CSKT on the Flathead River below Flathead Lake captured 17 bull trout ranging from 191 – 851 mm (Dos Santos et al. 1988). Bull trout were also present in the Jocko River. On the Flathead Reservation, bull trout were found in Tabor Reservoir (St. Marys Lake), Mission Reservoir, and McDonald Lake (Hansen and DosSantos 1995a). Each was formerly connected to the Flathead River but their populations became isolated by irrigation diversions. Dry Lake Creek is a tributary of Tabor Reservoir. Bull trout redds numbered zero from 1986 – 1992, 1 in 1993, and 3 in 1994 (Hansen and DosSantos 1993a, 1993b; MBTSG 1996c). Mission Creek is a tributary of Mission Reservoir. An average of 2.5 redds were counted from 1986 – 1992 (Hansen and DosSantos 1993a). Bull trout redd counts a tributary of McDonald Reservoir averaged 23 and ranged from 11 – 39 between 1986 and 1994 (MBTSG 1996c).

Above Flathead Lake bull trout from tributaries of all forks of the Flathead and Swan Rivers originally had a mixture of life history variants, including adfluvial stocks that migrated to and matured in Flathead Lake. The adfluvial fish was the dominant type. Access of bull trout into the Swan River drainage was blocked by construction of Big Fork Dam in 1902. A fish ladder installed in the 1920's never worked properly and was disabled in the late 1980's to prevent the migration of non-indigenous lake trout and lake whitefish from Flathead Lake into the Swan River drainage (MBTSG 1996a). Tag returns indicated that a limited number of bull trout still emigrate from the Swan River into Flathead Lake but they are unable to return upstream (Leathe and Enk 1985). One bull trout tagged in Goat Creek, a tributary of the Swan River, migrated downstream through Swan Lake, over Big Fork Dam, into Flathead Lake and was recaptured nine months later 54 km up the Flathead River above the Lake (Leathe and Enk 1985). Thus, this fish apparently "strayed" into the Flathead River for spawning because access to its natal stream was blocked, which may provide some insight into metapopulation dynamics. Above Big Fork Dam, resident, fluvial and adfluvial bull trout occur throughout the Swan River drainage (Leathe and Enk 1985; MBTSG 1996a; Kanda et al. 1997).

Evermann (1892) noted that bull trout were present in Swan Lake. In 1937 – 1938, the U.S. Forest Service reported that bull trout were present in Barber, Buck, Cat, Cedar, Cold, Condon, Cooney, Dog, Elk, Fatty, Glacier, Jim, Lion, Piper, Pony, and Rumble Creeks, as well as the Swan River, Swan Lake and Holland Lake (Flathead National Forest 1948). Few bull trout were captured in the Swan River during studies by MDFWP in the 1980's (Leathe and Enk 1985). The river was thought to serve primarily as a migratory corridor linking Swan Lake with these tributaries (Leathe and Enk 1985; MBTSG 1996a). These adfluvial bull trout mature in the lake then return to natal streams to spawn.

Bull trout spawning was recorded in 16 of the 53 named tributaries in the Swan drainage and juvenile rearing was recorded in ten others (Leathe and Enk 1985; MBTSG 1996a; Weaver 1997a, 1997b). Spawning was observed in Buck, Cedar, Cold, Condon, Cooney, Dog, Elk, Glacier, Goat, Jim, Lion, Lost, Piper, Soup, Squeezer and Woodward Creeks. Of these, Elk, Goat, Lion and Squeezer Creeks had consistently high numbers of redds (68 percent of all spawning bull trout in the Swan River drainage occurs in these streams – MBTSG 1996c); Cold, Jim, Lost, Piper and Woodward Creeks had consistently low numbers of redds; and the remainder did not have redds every year. Bull trout redds have been counted annually in four selected tributaries and intermittently in five tributaries in the Swan River drainage since 1982 (Table A10). Bull trout redd counts in the four primary index streams increased (tripled) from 1982 through 1998 (n = 612) and decreased about 30 percent by 2004 (n = 435). In 2004, 592 redds were recorded from basin-wide surveys in the Swan River (MDFWP 2005). The reduced counts in recent years in partly related to the fact that a consumptive fishery for bull trout is permitted in the Swan drainage. Anglers are allowed one bull trout in possession and maximum of two annually.

Bull trout redds were also observed in inlets of two lake (Holland and Lindberg) in the Swan drainage that were isolated from the Swan River. Redd counts in Holland Creek varied from 10-18 annually (MBTSG 1996c). The creek has a barrier falls about 0.5 km above its outlet in Holland Lake. Twenty-four redds were counted in the upper Swan River above Lindberg Lake in 1994 (MBTSG 1996c).

Hungry Horse Dam blocked adfluvial migrations into the South Fork of the Flathead River in 1951. Above the dam resident, fluvial and adfluvial stocks still occur in many tributaries (Gaffney 1959; May et al. 1988; MBTSG 1995e; Kanda et al. 1997; Weaver 1997a, 1997b). Although adfluvial fish from the south fork entrain at the dam, many now mature in Hungary Horse Reservoir (MBTSG 1995c). A survey by the U.S. Forest Service in 1937 – 1938 recorded the presence of bull trout in several tributaries of the lower South Fork, including Clayton, Deep, Flossy, Forest, Hungary Horse, Logan, Quintonkin, Riverside, Sullivan, Wheeler, and Wounded Buck Creeks (Flathead National Forest 1948). Bull trout habitat in the lower reaches of each of these streams was inundated by Hungry Horse Reservoir. The Forest Service survey also noted the presence of bull trout in several tributaries of the upper South Fork (i.e., the free flowing segment above the head of Hungry Horse Reservoir), including Bartlett, Blackbear, Bunker, Gordon, Mid, Spotted Bear, Twin (lower), Twin (upper), Youngs and places other than those listed (Flathead National Forest 1948). Disjunct (i.e., self reproducing and functionally isolated) adfluvial bull trout were also present in Big Salmon and Doctor Lakes (Flathead National Forest 1948). The fish in Big Salmon Lake spawn in the inlet – Big Salmon Creek, migrating as much as 8.8 km upstream to a barrier falls (MBTSG 1995e). Those of Doctor Lake are assumed to spawn in Doctor Creek upstream from the Lake (MBTSG 1995e).

Table A10. Bull trout redd counts in the Swan River drainage, Montana, 1982-2004 (Data from Weaver 1995 and B. Marotz, MDFWP – Kalispel, pers. comm.). Large type = streams where redd counts were made annually. Small type = streams where redd counts were made intermittently.

Stream	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Elk	56	91	93	19	53	162	201	186	136	140	143
Goat	33	39	31	40	56	31	46	34	27	31	17
Lion	63	49	88	26	46	33	65	84	58	94	100
Squeezer	41	57	83	24	55	64	9[a/]	67	42	101	115
Total	193	236	295	109[a/]	210	290	321[a/]	371	263	366	375

Stream	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Elk	139	195	150	176	186	259	261	209	165	152	168	157
Goat	64	66	32	52	85	71	46	71	91	54	80	67
Lion	123	141	170	181	190	141	135	120	132	102	92	117
Squeezer	106	91	149	117	125	141	59[a/]	105	114	122	85	94
Total	432	493	501	526	586	612	501[a/]	505	502	430	425	435[a/]

Stream	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Cold	1	9	6	--	--	--	--	--	--	5	--	--	--	21
Jim	--	7	6	--	--	--	--	39	22	40	45	43	53	56
Lost	11	7	19	--	--	--	--	--	13	6	--	--	17	21
Piper	0	0	1	--	--	--	--	25	--	18	--	--	--	10
Woodward	0	3	--	--	--	--	--	--	--	36	--	--	--	77

[a/] High flows may have obliterated some redds.
-- No counts made that year.

Bull trout populations in Hungry Horse Reservoir have been monitored since 1958 by gill netting. Catches made from 1983 – 1987 were consistent from year to year and similar to those dating back to 1958: 4.7 – 6.3 bull trout per net set in spring samples and 2.0 – 6.7 bull trout per net set in fall samples (May et al. 1988). Bull trout captured ranged from 178 – 914 mm in total length (May et al. 1988). MDFWP estimated the bull trout population in Hungry Horse Reservoir at 2,932 adults in 1993 and 3,194 adults in 1994 (Weaver 1997a, 1997b).

MDFWP inventoried bull trout spawning sites throughout the South Fork Flathead River in 1993. All tributaries suspected of providing spawning habitat for bull trout were surveyed (Weaver 1997a, 1997b). Spawning bull trout (# redds) were located in Babcock (n = 4), Bunder (n = 2), Danaher (n = 9), Gordon (n = 35), Quintonkin (n = 5), Rapid (n = 12), Salmon (Little, n = 56), Salmon (Big, n = 92), Spotted Bear (n = 9), Sullivan (n = 10), Wheeler (n = 12), White River (n = 39), Wounded Buck (n = 22) and Youngs (n = 40) Creeks. No spawning bull trout were observed in Bar, Bartlett, Basin, Burnt, Cabin, Calf, Camp, Clark, Doris, Foolhen, Gordon, Hahn, Harrison, Holbrook, Jenny, Limestone, Marshall, Mid, Otter, or Spring Creeks and South Fork of the White River. (Note: Although spawning adults were not found, many of the latter tributaries had juvenile bull trout rearing in them.)

Based on these findings eight tributaries were selected as index streams for long-term monitoring of redd counts. Quintonkin, Sullivan, Wheeler and Wounded Buck Creeks (all tributaries of Hungry Horse Reservoir) were to be monitored annually. Gordon Creek, Little Salmon Creek, White River, and Youngs Creek, all of the South Fork upstream of the Reservoir, were to be monitored less frequently because they were located in remote wilderness that was more difficult to access. Redd counts made for each of these tributaries from 1993-2004 are recorded in Table A11. Bull trout redd counts in the South Fork Flathead River have generally increased (doubled) between the time the first counts were made (1993) until present (2004). Angler harvest (one bull trout per day with two bull trout annual limit) was allowed in 2004.

Kanda et al. (1997) collected bull trout genetic samples from the following South Fork locations: Hungry Horse Reservoir (n = 32 adults), Wounded buck Creek (n = 35), Sullivan Creek (n = 59), Spotted Bear River (n = 26), Big Salmon Creek (n = 55), White River (n = 67), and Youngs Creek (n = 25).

Table A11. Bull trout redd counts for South Fork of Flathead River, Montana, 1993-2004. (Data from B. Marotz, MDFWP- Kalispel, pers. comm.)

Tributary Reservoir	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Quintonkin	5	3	7	4	0	11	15	15	17	21	4[b/]	18
Sullivan	25	8	--	52	50	54	55	45	51	18	45	62
Wheeler	12	10	1	3	1	4	12	23	25	12	17	15
Wounded Buck	22	29	34	41	14	5	3	3	9	5	10	3
Subtotal	64	50	42	100	65	74	85	86	102	56	76	98
Gordon	35	44	46	58	30	--	99	--	120	--	--	140
Little Salmon	56	47	43	134	100	--	138	--	111	--	--	71
White River	39	60	45	86	31	--	76	--	76	--	--	70
Youngs	40	24	34	74	43	--	85	--	61	--	--	100
Subtotal	170	175	168	353	204	--	398	--	368	--	--	381
Combined Total	234	225	210[a/]	453	269	74	483	86	470	56	76	479[a/]

[a/]High flows may have obliterated some redds. [b/] Ice may have obscured some redds. -- No counts made that year.

Above Flathead Lake, bull trout in the North and Middle forks of the Flathead River and Stillwater River were investigated by Schultz (1941), Flathead National Forest (1948), Block (1955), Stefanich (1958), Kinnie (1960), Morton (1968), Fraley et al. (1981), Shepard et al. (1984), Fraley and Shepard (1989), Spencer et al. (1991), and Weaver (1997a, 1997b). Bull trout in the Middle Fork, South Fork, and Stillwater and Whitefish Rivers still maintain their connection with Flathead Lake. In addition, some adfluvial bull trout, mature in large lakes (e.g., Lake McDonald) in Glacier National Park and migrate up tributaries to spawn (Schultz 1941).

Bull trout were present in the Flathead River between the inlet at Flathead Lake and the confluence of the North and South Forks (Block 1955). This stretch of the Flathead is often called “Lower Flathead” by local fish managers. The presence of bull trout was detected in the North Fork Flathead River and its following tributaries: Akukla (formerly called “Indian” or “Oil”) Lake, Big Creek, Bowman Creek, Coal Creek, Hollowat Creek, Hay Creek, Kintla Creek (also Kintla and upper Kintla Lakes), Kishenean Creek, Logging Creek (also Logging Lake), Moose Creek, Quartz Creek (also lower, middle and upper Quartz Lakes), Red Meadow Creek, Trail Creek, and Whale Creek (Schultz 1941; Flathead National Forest 1948; Block 1955; Morton 1968; MBTSG 1995d;).

In the Middle Fork Flathead River bull trout were detected in the main stem and following tributaries: Bear, Bowl, Deerlick, Dolly Varden, Fish, Granite, Harrison, How, Jara, Lake, Lincoln, Lodgepole, Long, McDonald, Morrison, Nyack, Ole, Park, Schaffer, Sheep, Snyder, Strawberry, Twenty-five Mile and Vinegar Creeks (Schultz 1941; Flathead National Forest 1948; Stefanich 1958; Kinnie 1960; Morton 1968). Bull trout were also recorded from Harrison Lake, Lower and Upper Isabel Lakes, McDonald Lake in the Middle Fork drainage (Schultz 1941; Morton 1968).

Fraley and Shepard (1989) determined that bull trout spawned in 28 tributaries of the North and Middle Forks. Juveniles were also collected from each of these streams (Fraley and Shepard 1989). Tributaries used in the Middle Fork included: Basin, Bear, Bowl, Charlie, Clack, Coal, Dirtyface, Dolly Varden, Elk, Granite, Lake, Lodgepole, Long, Morrison, Nyack, Ole, Park, Schafer, Strawberry and Trail Creeks. Important spawning tributaries in the Middle Fork were Granite, Lodgepole, Morrison, Ole and Trail Creeks (Fraley and Shepard 1989; MBTSG 1995d). Tributaries used in the North Fork included Big, Coal, Coal (South Fork), Hollowat, Mathias, Red Meadow, Shorty, Starvation, Trail, and Whale Creeks (in the United States) and Cabin, Couldry, Howell, Kishenehn and Sage Creeks in Canada (Fraley and Shepard 1989; MBTSG 1995d). Important tributaries in the North Fork included Big, Coal, Trail and Whale Creeks (Fraley and Shepard 1989; MBTSG 1995d). Redd counts have been made in selected index tributaries in the Middle and North Forks (Weaver 1997a, 1997b; Rieman and Myers 1997) since 1979 (Table A12).

Table A12. Bull trout redd counts in selected index tributaries of the Middle and North Forks of the Flathead River, Montana, 1979-1992. Data from Weaver (1997a, 1997b), Rieman and Myers (1997), and B. Marotz MDFWP – Kalispel (pers. comm.)

Drainage: Stream	Redd Counts												
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
North Fork:													
Big	10	20	18	41	22	9	9	12	22	19	24	25	24
Coal	38	34	23	60	61	53	40	13	48	52	50	29	34
Trail	34	31[a/]	78	94	56	32	25	69	64	62	51	65	27
Whale	35	45	98	211	141	133	94	90	143	136	119	109	61
Total	117	130	217	406	280	227	168[b/]	184	277	269	244	228	146
Middle Fork:													
Granite	14	34	14[a/]	34	31	47	24	37	34	32	31	21	20
Lodgepole	32	14	18	23	23	23	20	42	21	19	43	12	9
Morrison	25	75	32[a/]	86	67	38	99	52	49	50	63	24	45
Ole	--	19	19	51	35	26	30	36	45	59	21	20	23
Subtotal	71	142	83	194	156	134	173[b/]	167	149	160	158	77	97
Total (Flathead drainage)	189	272[a/]	300[a/]	600	436	361	341[b/]	351	426	429	402	305	243

Drainage: Stream	Redd Counts												
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
North Fork:													
Big	16	2	11	14	6	13	30	34	32	22	12	12	11
Coal	7	10	6	13	3	5	14	7	3	0	0	1	3
Trail	26	13	15	28	8	9	17	21	42	27	26	14	34
Whale	12	46	32	28	35	17	40	49	68	77	71	34	41
Total	61	71	64	83	52	44	101	111	145	126	109	61	89
Middle Fork:													
Granite	16	9	18	25	4	12	22	37	26	18	18	17	17
Lodgepole	13	9	6	9	8	5	7	11	3	17	12	10	6
Morrison	17	14	21	28	9	39	35	30	44	40	30	21	10
Ole	16	19	6	16	10	14	22	26	33	29	21	21	14
Subtotal	62	51	51	78	31	70	86	104	106	104	81	69	47
Total (Flathead drainage)	123	122	115	161	83	114	187	215	251	230	190	130	136[b/]

[a/]Counts may be low due to incomplete survey.
[b/]High flows may have obliterated some redds.

A declining trend (P = 0.05) in redd counts was evident in certain tributaries in the Flathead and Swan River drainages (Rieman and Myers 1997). Redd counts in tributaries of the Swan River drainage appeared to be stable or increasing whereas redd counts in the seven of the eight tributaries in Middle and North Forks had decreased. Combined redd counts in the tributaries had decreased from a peak of 600 (in 1982) to 83 (in 1996) (Weaver 1997a, 1997b) before recovering somewhat by 2000 (n = 230 redds) then declining again in recent years (130 – 136 in 2003 and 2004).

Kanda et al. (1997) collected bull trout for genetic analysis from the following tributaries of the Middle Fork: Bear (n=25), Granite (n=17), Ole (n=16), and Schafer (n=43) creeks. They also collected bull trout from the following tributaries of the North Fork: Big (n=51), Coal (n=24), Howell (n=16), Trail (n=53), and Whale (n=29) creeks, and the Upper North Fork main stem (n=21).

Bull trout were recorded from the following locations in the Stillwater drainage: Fitzsimmons, Good, Griffin, Logan, Martin and Sunday creeks, and Stillwater and Whitefish Rivers (Flathead National Forest 1948; Block 1955; Hanzel 1961; Peters 1964). Presence of bull trout was also noted in Upper and Lower Stillwater Lake, Tally Lake, Whitefish and Upper Whitefish Lakes in the Stillwater drainage (Flathead National Forest 1948; Peters 1964). Bull trout were captured in the Stillwater River (n=25) and Swift Creek (n=24), a tributary of the Stillwater River, in 1992-1993 (Kanda et al. 1997).

Disjunct populations of bull trout were present in Akukala, Bowman, Cerulean, Cyclone, Frozen, Logging, Middle Quartz, Quartz and Trout lakes in the North Fork drainage (MBTSG 1995d). Bull trout were also present in Arrow Lake during the 1960's but none have been caught there in recent surveys (MBTSG 1995d). Bull trout in Cyclone Lake apparently migrated downstream to spawn in the outlet: five redds were counted over a distance of about 0.5 km in 1994 (MBTSG 1995d).

Disjunct populations also occur in the Middle Fork drainage in Harrison Lake, Lower Isabel Lake and Lake McDonald (MBTSG 1995d). Little information is available on the status of these populations.

In the Stillwater and Whitefish Rivers, disjunct bull trout populations occur in Lower and Upper Stillwater Lakes, Tally Lake, Whitefish Lake and Upper Whitefish Lake (MBTSG 1995d). At present, these populations are threatened by non-indigenous northern pike (*Esox lucius*), lake trout (*Salvelinus namaycush*), and opossum shrimp (*Mysis relicta*) (MBTSG 1995d).

In the Bitterroot River drainage resident and fluvial bull trout apparently still reside in many tributaries (Clancy 1991, 1993; Jakober 1995; MBTSG 1995b; Jakober et al. 1998). Resident populations occur in headwaters above migration barriers and are common. Fluvial populations that spawn in tributaries and mature in the Bitterroot main stem are uncommon.

The earliest reference to bull trout in the Bitterroot drainage was a specimen collected at the St. Marys Mission (near Stephensville, Montana) by Dr. George Suckley in 1853 or 1854 and deposited in the United States National Museum (Smithsonian). This fish was described by Dr. Charles Girard as *Salmo spectabilis* (Girard 1856). Suckley (1858) noted that the specific epithet used by Girard was preoccupied and described bull trout from various locations in the Pacific Northwest under a variety of scientific names, the first being *S. confluentus*. Use of the Bitterroot River by adfluvial bull trout from Lake Pend Oreille has not been documented although Evermann (1893) reported that "salmon trout" (i.e., bull trout) weighing 12-14 pounds had been taken from the Bitterroot River, near Missoula. Oral testimony indicated that large, migratory bull trout were present during the 1920's and 1930's (MBTSG 1995b). At present large (>450 mm) migratory bull trout are rare in the main stem of the Bitterroot River from the mouth to the junction of the East and West Forks (MBTSG 1995b).

Bull trout were collected during electrofishing surveys made by MDFWP in the 1950's and 1960's in the East and West Forks of the Bitterroot River; in Burnt Fork, Hughes, Lolo, Lost Horse, Lost Park, Meadow, Moose, Skalkaho, and South Fork Skalkaho Creeks; and in Painted Rocks Reservoir (Whitney 1955; MBTSG 1995b).

Today, resident bull trout appear to be present in good numbers throughout the Upper East Fork drainage (upstream of Bertie Lord Creek), Upper West Fork drainage (upstream of Painted Rock Reservoir), Blodgett Creek drainage, Burnt Fork drainage, Fred Burr Creek drainage, Skalkaho Creek drainage and Sleeping Child Creek drainage (Clancy 1991, 1993; MBTSG 1995b).

A report by Clancy (1996) provided a map of the known distribution of bull trout in the Bitterroot drainage as of 1995 based on electrofishing sampling at over 500 locations in the main stem and tributary streams (See Clancy 1991, 1993, 1996). Bull trout were present in the main stem, and throughout the East and West Forks in low numbers. They were abundant in the middle and upper reaches of the East and West Forks and in some tributaries.

- Tributary streams entering from the east bank (streams are in order from the mouth to headwaters of the Bitterroot River, with tributaries of that stream listed in parentheses) where bull trout were detected included Upper Burnt Fork (and its tributary Gold Creek), Willow Creek, Grid Creek (St. Clair Creek), Skalkaho Creek (Bear Gulch, Daly, Railroad, and Weasel Creeks), Sleeping Child Creek (Divide Creek), and Upper Rye Creek.
- Tributary streams entering the main stem of the Bitterroot River from the west bank that contained bull trout included: One Horse Creek (tributary of Lolo Creek), Sweeny Creek, Bass Creek, Kootenai Creek, Big Creek, Sweathouse Creek, Bear Creek, Fred Burr Creek (Mill Creek), Sawtooth Creek, Roaring Lion Creek, Lost Horse Creek (South Lost Horse Creek), Tin Cup Creek, and Chaffin Creek.
- Tributary streams entering the East Fork that contained bull trout included: Gilbert Creek, Warm Springs Creek (Crazy, Fire, Prayer, Porcupine and Wiler Creeks), Upper Camp Creek, Tulan Creeks, Meadow Creek (Buck and Swit Creeks), Martin (Bush, Moose, Reynolds and Sig Creeks), Orphan Creek, Cliffford Creek and Star Creek.
- Tributary streams entering the West Fork that contained bull trout included: Lower Trapper Creek, Piquett Creek, Lower Boulder Creek, Nez Perce Fork

(Soda Springs, Little West Fork, Watchtower, North Fork and Sheephead Creeks), Little Boulder Creek, Blue Joint Creek, Overwhich Creek (Straight Creek), Hughes Creek, Chicken Creek, Deer Creek, Woods Creek, Johnson Creek, Beaver Creek and Sheep Creek.

These tributaries had varying levels of bull trout.

Six sites in the main stem Bitterroot River and in its east and west forks have been monitored by electrofishing over a period of several years (Clancy 1991, 1993, 1996, 1998, 2003; Clancy and Javorsky 2001). Sites ranged from 3.5 – 8.2 km in length. Sites were in the main stem near Stevensville (in 1989, 1991, 1993 – 1994, 1996, 2001); main stem near Hamilton (in 1992 and 2001); main stem near Darby (in 1982 – 1985, 1989 – 1990, 1993, 1995 – 1996, 1999, 2002); East Fork at RKM 4.0 (in 1998, 2000 – 2001); East Fork at RKM 19.3 (in 1995, 1997, 2000 – 2002); and West Fork at 1.9 (in 1995, 1997 – 1998, 2002). Bull trout were occasionally collected during these surveys but numbers were too small to estimate populations or densities. Apparently, small numbers of migratory type bull trout with fluvial life histories migrate out of spawning tributaries to overwinter in one of the forks or main stem.

The majority of individuals in tributary populations are principally resident type bull trout. Individuals > 200 mm are rare but small sized individuals (< 200 mm) are present in varying abundance (Clancy 1991, 1993, 1996, 1998, 2003; Clancy and Javorsky 2001). Twenty-eight sites on 20 tributaries have been monitored for several years for the purpose of estimating bull trout populations and densities (Table A13). Bull trout densities have ranged from “rare” up to 540 bull trout, > 127 mm (5 inches) TL, per kilometer. Bull trout abundance is variable but stable in most of these tributaries. Irrigation diversions have chronically deteriorated tributaries and portions of the main stem, impeding movements of migratory bull trout and fragmenting their populations in this system. Catastrophic fires have also affected bull trout distribution in the Bitterroot drainage.

Table A13. Densities of bull trout (principally resident life history type > 125 mm TL) in selected index tributaries in the Bitterroot River drainage, Montana. Data compiled from Clancy (1991, 1993, 1996, 1998, 2003) and Clancy and Javorsky (2001). Bull trout densities were estimated from graphs and subject to error.

Location (RKM)	Year(s) sampled	Bull trout density (#/km)
Stevensville District (main stem tributaries)		
Burnt Fork Creek (RKM 30.9)	1994 – 1996, 2000	155 – 337
Gold Creek (RKM 0.5)	1990 – 1991, 1996	59 – 83
Darby District (main stem tributaries)		
Daly Creek (RKM 1.1)	1984 – 1987, 1989 – 1990, 1999, 2001 - 2002	248 - 416
Divide Creek (RKM 0.2)	1991, 1996	129 - 132
North Rye Creek (RKM 2.4)	1989 – 1991, 1996 – 1997, 2000	Bull trout "rare"
Rye Creek (RKM 20.0)	1989 – 1991, 1996 – 1997, 2000	Bull trout "rare"
Skalkaho Creek (RKM 21.1)	1991 – 1992, 1994, 1998 – 1999	145 – 540
Skalkaho Creek (RKM 27.0)[1]	1990 – 2002	132 – 297
Skalkaho Creek (RKM 31.5)	1991 – 1994	99 – 274
Sleeping Child Creek (RKM 16.4)[2]	1985 – 1986, 1989 – 2002	66 – 99
Sleeping Child Creek (RKM 21.6)[2]	1989, 1991, 1996	50 – 132
Sleeping Child Creek (RKM 25.3)[2]	1990 - 1991	17 - 33
Sula District (East Fork tributaries)		
Upper East Fork (RKM 41.0 or 50.5)	1992, 1995	26 – 142
Martin Creek (RKM 2.1)	1992 – 1994, 1997, 1999, 2002	17 – 50
Martin Creek (RKM 4.0)	1992, 1995	33 – 40
Meadow Creek (RKM 9.0)	1989 – 1990, 1994 – 1996, 2000 – 2002	76 – 248
Meadow Creek (RKM 11.7)	1989, 1990	83 – 119
Moose Creek (RKM 2.3)	1989 – 1993, 1997, 1999, 2001 – 2002	3 – 139
Moose Creek (RKM 5.8)	1992 – 1994	66 – 99
Tolan Creek (RKM 8.2)	1989 – 1990, 1996 – 1997	99 – 122
Warm Springs Creek (RKM 5.6)	1992, 1994 – 1995, 2000 – 2002	3 – 26
Warm Springs Creek (RKM 11.3)	1992 – 1995	198 – 363
West Fork District (West Fork tributaries)		
Upper West Fork (RKM 48.8)	1991 – 1992, 1995, 1998 – 1999	Bull trout "present"
Blue Joint Creek (RKM 6.8)	1993 – 1995	Bull trout "present"
Boulder Creek (RKM 3.2)	1992	Bull trout "abundant"
Hughes Creek (RKM 14.5)	1996, 1999	No mention of bull trout
Overwhich Creek (RKM 3.2)	1984, 1994 – 1995, 1998 - 1999	Bull trout "present"
Slate Creek (RKM 1.9)	1991 – 1993, 1999	Bull trout "common"

[1] Estimates of bull trout > 203 mm in Skalkaho Creek (RKM 27.0) were: 20 (1990), 18 (1991), 16 (1992), 8 (1993), 6 (1994), 24 (1995), 18 (1996), 17 (1997), 28 (1998), 35 (1999), and 42 (2000).
[2] Bull trout population in Sleeping Child Creek small and difficult to enumerate.

Milltown Reservoir and Upper Clark Fork (including Blackfoot River)

Milltown Dam (approx. 6 m high at RKM 586.3) near Missoula, Montana is located at the junction of the Clark Fork and Blackfoot Rivers. This dam blocked upstream migration of fluvial bull trout to spawning sites in the upper Clark Fork and Blackfoot rivers and their tributaries commencing in 1907. The dam held back contaminated sediment that washed down the Clark Fork River from mining and smelting operations in

Helena and Butte, Montana. On 20 December 2004, the U.S. Environmental Protection Agency approved a plan to remove Milltown Dam, which included cleanup of the contaminated sediments. Pollution abatement is scheduled to commence in 2005, with removal of the Dam to occur in 2006. Removal of this dam will restore the upper Clark Fork and Blackfoot Rivers to free flowing conditions and allow unrestricted fish passage.

Over a distance of 204.4 km from Milltown Dam, the Clark Fork is joined by 41 tributaries, including the Blackfoot River (RKM 586.6) plus its 26 tributaries, Rock Creek (RKM 614.3) plus its 31 tributaries, Flint Creek (RKM 671.9) plus its 12 tributaries, and Little Blackfoot River (RKM 717.1).

Information about bull trout in the Clark Fork and Blackfoot Rivers above Milltown Dam was found in Averett and Whitney (1959), Berg (1989), Pierce and Spoon (1989), Peters (1990); Pierce (1991), Montana Bull Trout Scientific Group (1995a, 1995c), Peters et al. (1997), Pierce et al. (1997, 2001, 2002), Swanberg (1997a, 1997b), Pierce and Schmetterling (1999), Pierce and Podner (2000), Schmetterling (2002) and Schmetterling et al. (2003). Once abundant, bull trout are now uncommon in this area. Bull trout populations in the Clark Fork main stem were depressed by mining pollution but remnant populations were found in two tributaries (Blackfoot River and Rock Creek). Milltown Dam disconnected these populations by blocking access of mature fluvial fish, entrained by the dam during juvenile or post-spawning out-migrations, from their natal tributaries. Bull trout redd counts made in 1996 were 160 in the Rock Creek drainage and 198 in the Blackfoot River drainage (Peters et al. 1997). Spawning escapement was estimated at 352-634 individuals in Rock Creek and 436-634 in the Blackfoot River.

Evermann (1892) noted that the upper Clark Fork was ruined by mining and ore processing operations, but the Little Blackfoot supported bull trout. Electrofishing surveys made by MDFWP in the 1950's and 1960's recorded the presence of bull trout in the Clark Fork River main stem, Rock Creek and several tributaries of Rock Creek (Bobcat, Butte Cabin, Cinnamon Bear, Cougar, East Fork Rock Creek, Hogback, Ranch and Little Stony Creek (Peters 1964; MBTSG 1995c). Bull trout were also present in Georgetown, Kaiser, Moose, Silver and Storm Lakes and East Fork Reservoir in the Rock

Creek drainage. An estimated 2,515 bull trout were harvested from the main stem of Rock Creek in 1958 – 1959 (Averett and Whitney 1959). In 1959, 120 bull trout were harvested in Rock Creek tributaries. Of these, 103 were caught in Ranch Creek (Smith 1960). Anglers also harvested bull trout in Cougar, Gilbert, Stony, Welcome, and Wyman Creeks during this survey. In 1993, 203 bull trout were caught in Rock Creek (MBTSG 1995c).

Remnant populations of bull trout still occur in Boulder Creek, Harvey Creek, Little Blackfoot River, Racetrack Creek, and Warm Springs Creek, which are all tributaries of the Upper Clark Fork (MBTSG 1995c). These populations appear to be the resident life history form and restricted to the headwater portions of these streams.

The migratory form as well as the resident form still occurs in good numbers in Rock Creek and many of its tributaries. Bull trout abundance in the Rock Creek main stem downstream of the confluence of Welcome Creek was 49, 95 and 16 bull trout (> 254 mm TL) per 1.6 km in 1986, 1989, and 1993 (MBTSG 1995c). Bull trout were still present in most streams noted in the 1950's and 1960's surveys noted above but not Cinnamon Bear or Little Stony Creeks. Additionally, bull trout were found in Flint and Copper Creeks (MBTSG 1995c).

Evermann (1892) noted the presence of bull trout in the Blackfoot River. Bull trout were collected during electrofishing or creel surveys in the main stem and North Fork of the Big Blackfoot River and several tributaries of the Blackfoot River (Peters 1964; MBTSG 1995a). Bull trout (> 300 mm TL) abundance has ranged from about 3 – 8 bull trout per km in the lower main stem in the 1980's and 1990's with relatively greater densities in later years (MBTSG 1995a). From 1989 to 2002, bull trout (> 150 mm TL) densities fluctuated annually, but generally increased at an index site (Johnsrud Section) in the lower mainstem, from 5 bull trout per km in 1989 to 20 bull trout per km in 2002 (Pierce et al. 2004). At a second index site (Scotty Brown Bridge Section) in the lower main stem, bull trout densities (for fish > 150 mm TL) increased from 1/km in 1990 to 25/km in 2000, then declined to about 16/km in 2002 (Pierce et al. 2004). At an index site (Wales Creek Section) in the middle main stem, few (n = 3 in 2002) bull trout were captured (Pierce et al. 2004). Tributaries known to harbor bull trout in the Blackfoot drainage included the Clearwater River (including its west fork and Deer Creek) and Arrastra, Belmont, Copper, Cottonwood, Gold, Hogum, Landers Fork, Monture, Morrell, Placid, Poorman and Rock Creeks (Pierce 1991; MBTSG 1995a; Pierce and Podner 2000; Pierce et al. 2001, 2002, 2004). Bull trout abundance was low except in the North Fork and Montrose Creeks. Bull trout are present in many tributaries that enter the Blackfoot River from the North but are absent in most tributaries that enter from the south.

Ten bull trout were captured in the upper Blackfoot River (above the confluence of the North Fork) and implanted with radio transmitters between 13 March and 18 April 2002 and 18 March and 13 April 2003 (Pierce et al. 2004). Nine of the 10 ascended tributaries to spawn, indicating that this is a fluvial population. Five fish entered the North Fork between late May and mid July and, after spawning, those that survived (n =3) returned to the Blackfoot main stem in September to mid November to within 1.6 km of the overwinter site used the pervious year. Four fish entered Copper Creek between mid June and late July and, after spawning, those that survived (n =3) remained in Copper Creek over the winter. The post-spawning behavior of the fish in Copper Creek was thought to be related to isolation because of low flows. Discharge of the Blackfoot River was 410 – 560 cfs in October 2002. An earlier biotelemetry study (Swanberg and Burns 1997) found that adult bull trout spawning in Copper Creek in 1996 returned to overwinter sites in the Blackfoot River. Discharge of the Blackfoot River was 650 – 700 cfs in October 1996.

Bull trout redd counts have been made by U.S. Forest Service in five tributaries of the Big Blackfoot River since 1989 (Table A14). Counts have steadily increased in Monture Creek. In the North Fork, counts steadily increased from 1989 (n = 8) to 2000 (n = 123) then decreased steadily through 2003 (n = 41). In Copper Creek, redd counts were stable from 1989 – 1998 (n = 23 redds per year on average, range = 19 – 27 redds). Redd counts declined to 4 in 2003.

Table A14. Bull trout redd counts for five tributaries of the Big Blackfoot River, 1989 – 2003. (Data from Pierce et al. 2004.) Index sites counts except for ( ) indicates total counts. -- = counts not made.

Location	Redd counts in:														
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Copper	21	23	24	25	19	23	21	21 (35)	22 (41)	27 (44)	9 (38)	20 (44)	16 (37)	15 (38)	4 (18)
Dunham	--	--	--	--	--	--	--	--	--	--	--	--	--	11	6
Gold	--	--	--	--	--	--	--	--	--	--	--	--	--	6	4
Monture	10	--	25	34	45	49	60	65 (79)	61 (71)	60 (67)	65 (75)	74 (80)	94 (93)	93 (101)	80 (83)
North Fork	8	--	26	39	--	--	27	59	65	76	87	123	75	70	41 (50)
Total	39	23	75	98	64	72	108	145	148	163	159	217	185	195	135

Summary of and inferences regarding bull trout in the Pend Oreille/Clark Fork Basin

In summary, bull trout populations in the Pend Oreille / Clark Fork Basin have been fragmented by construction of hydroelectric projects. Population segments occur in:

1. The Lower Pend Oreille and Salmo river drainages (isolated by Waneta, Seven Mile and Boundary dams). The Salmo River population (isolated between Seven Mile and Boundary dams) is composed of resident and fluvial fish that utilize the Salmo River and its tributaries, and perhaps a few adfluvial fish that migrate from the Salmo River into Seven Mile Reservior. The Salmo River population is currently reproducing and appears to be stable. Redd counts increased slightly, from 180-196, between 1988 and 2003. Bull trout in Waneta Reservoir appear to be washouts from either the Salmo population or other upriver populations. There is currently no evidence of natural reproduction of bull trout in Waneta Reservoir.

2. The Middle Pend Oreille River, i.e., Boundary and Box Canyon Reservoir drainages (isolated between Boundary, Box Canyon and Albeni Falls dams). Few bull trout (n = 3) have been observed in Boundary Reservoir or its tributaries despite extensive sampling. One was collected in the reservoir at the mouth of Slate Creek, one in Sweet Creek (300 mm) and one found dead on the bank of Sullivan Creek about 0.5 km above the mouth (757 mm). To date, no evidence of natural reproduction has been found in the Boundary Reservoir drainage. Bull trout are rare in Box Canyon Reservoir. Between 1987 and 2004, a total of 19 bull trout were captured in the reservoir and 11 have been observed during electrofishing and snorkeling surveys or migration trapping conducted in 20 of 22 tributaries entering the reservoir. Seven of the 11 tributary fish were from one drainage (LeClerc Creek), including an adult female observed digging a redd in the West Branch in 2001. Other tributaries where bull trout were collected included Cedar (n = 2), Indian (n = 1) and Mill (n = 1) creeks. Migration trapping was conducted on 12 different tributaries between 1997 and 2000 (n = 6 – 11 tributaries sampled annually). Only one bull trout was captured in a migration trap (at Indian Creek) and that fish bore a fin clip indicating that it had originally been

tagged and released in a tributary of Lake Pend Oreille (Trestle Creek). Thus, there is currently no evidence that individuals with adfluvial life history are still present in the Box Canyon Reach. To date, little evidence has been gathered to indicate that natural reproduction of bull trout still occurs in the Box Canyon Reach, with the possible exception of LeClerc Creek.

3. Priest River (isolated by Outlet Dam on Priest Lake). A small population of adfluvial bull trout, and possibly resident bull trout, occurs in tributaries of upper Priest Lake. Redd counts from 1992-2003 indicate that this population segment is naturally reproducing and stable. Redd counts were higher from 2000-2003 than 1992-1995, but down slightly compared to 1996-1999. A small population of adfluvial bull trout spawn in the Middle Fork East River, a tributary of the Priest River below Outlet Dam. These fish retain a connection to Lake Pend Oreille. Redd counts ranged from 7-24 from 2001-2003.

4. Upper Pend Oreille River and Lake Pend Oreille drainages (isolated by Albeni Falls and Cabinet Gorge dams). Few bull trout are present in the Pend Oreille River below the lake, apparently because summer temperatures are above the thermal tolerance for bull trout. Bull trout from the Priest River (Middle Fork East River) use it as a migration corridor in the fall and spring to migrate to and from Lake Pend Oreille. The majority of bull trout found in tributaries of Lake Pend Oreille are the adfluvial type. Populations in individual tributaries are relatively low but they are reproducing successfully. Redd counts for all tributaries combined in 2004 (n = 873) was about the same as counts made in 1983 (n = 814), after a low count in 1995 (n = 320). However, numbers of redds in some tributaries have increased but decline in others. For example, the number of redds in the Lightning Creek drainage was 301 in 1983, compared to 92 in 1993 and 167 in 2004.

5. Lower Clark Fork drainage (isolated by Cabinet Gorge, Noxon Rapids, Thompson Falls and Milltown dams). Adfluvial, fluvial and resident bull trout are still present throughout this region in low numbers and some limited natural reproduction is still apparently occurring in tributaries, although it has not been quantified. The conjecture that natural reproduction still occurs is supported by the fact that each year large, sexually mature, adfluvial bull trout congregate in the Clark Fork River at the base of Cabinet Gorge Dam. Assuming that these fish are trying to return to natal streams, this could be taken as evidence that some natural production must still be occurring.

6. Lower Flathead River drainage (isolated by Thompson Falls and Kerr dams). Bull trout are rare in this region. Only 17 were collected during electrofishing surveys from 1983-1986.

7. Upper Flathead River drainage (isolated above Kerr Dam). This population segment is composed mainly of adfluvial bull trout, with a few resident and fluvial individuals. Connectivity to Flathead Lake was retained by bull trout residing in the North and Middle Forks and Stillwater River but lost for bull trout residing in South Fork which is isolated by Hungry Horse Dam. Adfluvial fish now use Hungry Horse Reservoir instead of migrating to Flathead Lake. Bull trout redd counts have been variable (n = 83 – 600) in the North and Middle Fork drainages since counts began in 1979 (n = 189). The 2004 count was 136 redds. Bull trout redd counts in the South Fork have been variable (n = 74-479) since counts began in 1993 (n = 234). The 2004 count was 479 redds.

8. Swan River drainage (isolated above Big Fork Dam). This population is composed mainly of adfluvial bull trout that mature in Swan Lake, with smaller numbers of resident bull trout. The Swan River is principally a migration corridor for bull trout migrating between the lake and headwater tributaries. The bull trout population in this system is strong. Redd counts in four index tributaries increased steadily (tripled) from 1982 (n = 193) to 1998 (n = 612). In 2004, the

redd count in these tributaries was 435. The lower number of redd counts in recent years is partly a reflection that limited harvest (one bull trout in possession, maximum two per year limit) is now in force in the drainage.

9. Bitterroot River drainage (isolated from the Clark Fork by a dry stretch near the mouth owing to irrigation pumping). This population segment is composed mainly of resident bull trout that reside in tributaries, with a few fluvial fish that migrate into the main stem, East Fork or West Fork. Resident populations in tributaries vary from 0 to over 500 individuals, > 125 mm T.L., per kilometer. The presence of fluvial fish has been detected in the main stem, East Fork and West Fork, but insufficient numbers have been captured to estimate populations or densities.

10. Upper Clark Fork drainage, including the Big Blackfoot River (isolated above Milltown Dam). This population segment is composed of resident and fluvial forms of bull trout. Decades of mining and ore processing pollution limited bull trout distribution in the Clark Fork main stem and resulted in their confinement to tributaries, in particular Rock Creek and the Big Blackfoot River. Fluvial bull trout from each of these tributaries migrated below Milltown Dam. Fluvial bull trout residing in tributaries of Rock Creek and the Big Blackfoot River also migrated into each river. Bull trout populations in each of these rivers are stable. For example, redd counts in five index tributaries of the Blackfoot River have fluctuated from 23-135 since counts began in 1989 (n = 39). In 2004, the count was the highest for the period of record (n = 135).

Our examination of the reports from each of these population segments revealed three interesting similarities. First, redd counts responded positively and immediately to closure of legal harvest. Second, redd counts appeared to be influenced by local and regional drought cycles, especially by droughts that lasted for multiple years. Bull trout redd counts were also reduced at some locations in the fall of 1997, which may have been related to high runoff that year. We collected several bull trout in Lake Roosevelt following this event and believed they had come from upstream areas, so one possible explanation for the low bull trout redd counts in 1997 is that some fish were entrained below dams and were blocked from returning to their natal streams. Third, there is a hint in the redd count data of recurring peaks, cycling at six year intervals (perhaps a reflection of the relative preponderance of first time age six adfluvial spawners) in many populations; although superimposition of environmental factors sometimes makes it difficult to detect this pattern. These factors make it difficult to detect any long term trends in bull trout abundance using redd count data, especially if the trend data is being used to predict (forecast) bull trout abundance in the future. We offer these observations in the spirit of fostering discussion about how these types of factors might be accounted for in future trend analyses of bull trout populations.

The absence of bull trout in the Box Canyon Reach is puzzling. In most areas of the Pend Oreille / Clark Fork Basin, juvenile and adult bull trout were easily captured in surveys similar to those performed in the Box Canyon Reach. Therefore, we believe that the dearth of bull trout in the Box Canyon reach (and its tributaries) is not owing to incomplete sampling, hence it is unlikely that future surveys will reveal significant numbers of bull trout in this reach.

Bull trout are present below (in the Salmo River drainage) and above (in the Priest Lake and Lake Pend Oreille drainages) Box Canyon in good numbers, so it is reasonable to assume that they were historically present in the Box Canyon Reach in good numbers (as was indicated by the direct observations of Barton W. Evermann, Charles H. Gilbert and David Starr Jordan between 1895 and 1908). Factors that could account for their demise include:

1. The temperature of the Pend Oreille River in the Box Canyon reach during August is currently much warmer than the cold river (an ideal trout stream) that was described by Gilbert and Evermann (1895), who visited the area on 9-15 August 1891. At the present time (2003-2004) temperatures in August throughout much of the reservoir were potentially lethal to bull trout. Increased temperature is likely caused by a combination of factors such as construction of hydroelectric

dams that impede water flow (allows water to warm up), reduced discharge of cold water into the main stem caused by withdrawals from tributaries or groundwater that might have otherwise entered the river, and reduced cover caused by deforestation. The cumulative impacts of these types of activities upstream in the Pend Oreille /Clark Fork Basin have resulted in high temperatures in the Pend Oreille River by the time the water flows over Albeni Falls Dam. The temperature remains high as this water passes through Box Canyon Reservoir. Although the temperature does not appear to increase as it passes through Box Canyon, it is probable that increased surface elevation in the Box Canyon Reach (caused by inundation associated with Box Canyon Dam) contributes to the retention of this heat. One way it may do this is by diluting cold water inflow that enters the reach. Because high temperatures are related to system-wide cumulative impacts, finding a solution to cure the temperature problem seems improbable. As summer temperature conditions in the main stem of the Box Canyon reach are presently inhospitable to bull trout and it appears little can be done to correct this problem, it places a premium on bull trout being able to migrate to a cold water refuge such as Lake Pend Oreille.

2. Extensive deforestation caused by prodigious logging and intense forest fires may have rendered tributary habitat unsuitable for bull trout production. [Timber harvest and fires were in historical times apparently more severe in the Box Canyon area than in other portions of the Pend Oreille / Clark Fork Basin (J. Maroney, Kalispel Tribe Department of Natural Resources, pers. comm.)]

3. Construction of Albeni Falls, Box Canyon, and Boundary dams may have blocked normal migration pathways. It seems clear that Albeni Falls Dam created a migration barrier since a United States Fish Commission biologist observed trout (species not described) passing freely up Albeni Falls in 1892. It is less certain if bull trout were able to move freely through the Z-Canyon and over Metaline Falls, which apparently served as barriers to the ascent of anadromous Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Oncorhynchus mykiss*).

However, these anadromous species had migrated about 1,250 km up the Columbia and Lower Pend Oreille Rivers, so their energy reserves were likely depleted. It is possible that a bull trout with a full store of energy may have been able to ascend these obstructions, especially since U.S. Fish Commission biologists who physically surveyed both the Z-Canyon and Metaline Falls did not consider them to be serious obstacles to fish migration. The revelation that a radio-tagged bull trout ascended the 9.5 m high Kootenai Falls on the Kootenai River, Montana, which was comparable in height and distance to Metaline Falls and formerly thought to be insurmountable to migratory salmonids, is suggestive that movement of bull trout through the Z-Canyon and Metaline Falls was not beyond the realm of possibility. If bull trout were able to move freely through this area, then construction of Box Canyon and Boundary dams blocked their migrations. Fragmentation of habitat in this manner could account for a rapid decline in population, especially if the majority of bull trout in the Box Canyon tributaries had a migratory (as opposed to resident) life history.